AN ANALYSIS OF FERTILIZER TRANSPORTATION REQUIREMENTS IN THE NORTH CENTRAL CROP REPORTING DISTRICT

by

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CHAPTER I

Introduction

This study is concerned with the projection of interregional transportation needs for delivery of fertilizer to an 11 county area in North Central Kansas. Fertilizer transport is only part, but an essential element, of transport requirements for Kansas Agricultural communities.

Long-term planning is essential to transportation industries. Carriers, shippers and public agencies must plan for future periods, based on estimates of transportation requirements. Intermodal competitive characteristics help determine the ways in which transport needs are met. Determining an optimum transport mix for a single commodity provides input into the planning of an entire system.

Rural American communities are accustomed to and dependent upon an extensive transportation system. Four major modes: railroads, highways, waterways, and pipelines, are used in varying combination to move inputs to production areas and products from farms and factories. Ownership of transport facilities are both public and private. Railroads and pipelines are largely privately owned while highways and waterways are publicly owned. Many communities are served by two or more of the major modes. Rural communities have come to expect both a high level of service and a choice among carriers and modes.

Even though the U.S. transportation system is one of the most extensive in the world, concern exists that it will not fully service the economic and social needs of rural areas in the future. Greater crop

yields coupled with increased demands for fertilizer, farm machinery and other farm inputs will increase the quantity of transportation service demanded. Periodically in the past, demands have been so great that existing transport supply has not been sufficient. A recent example is an equipment shortage lasting from the fall of 1972 into 1974. The shortage was the result of expanded marketings of farm crops, increased use of farm inputs, an unprecedented surge in exports, and strong expansion elsewhere in the economy.

Precise estimates of future transportation requirements in rural communities are not possible, however, projections of production trends and comparative transportation characteristics of major commodities will help provide a basis for estimating the need for interregional transport facilities.

Changing Conditions in the Transportation Industry

Transportation industries, like nearly all other American industries, are in a state of change. Fluctuating demands and increased costs cause concern about the future. Many railroads have abandoned or have announced intentions to abandon substantial portions of light density lines.[1]

Publicly-owned modes of transportation (highways and waterways) have enjoyed favorable conditions because of improved facilities. Expansion and improvement in highways, especially the Federal interstate system, have led to major shifts in transportation of perishable goods and livestock from rail to truck. Temporary equipment shortages have

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[1] Hagen, James A. "Light-Density Rail Line Operations: Overview of Issues," Symposium of Economic and Public Factors Influencing Light Density Rail Line Operations - January, 1973 - Pg. 1.

occurred in the trucking industry, but trucking capacities respond quickly to changes in demand for service. Higher energy costs increase trucking costs more than for other transportation modes, which may result in some shifting to the more energy-efficient modes.[2]

Waterway movements, though economical and energy efficient, are restricted geographically. However, comparative energy efficiency combined with two-way load possibilities make expanded water movement of fertilizer a realistic possibility.

Changing Conditions in the Fertilizer Industry

For centuries farmers have recognized the benefits of improving soil fertility, and man has identified and developed numerous methods for releasing and supplementing the growth potential of soil. The development of chemical fertilizer has been the major means of improving soil fertility. Between 1940 and 1970, consumption of fertilizer increased steadily in the United States. Nitrogen consumption increased more than 17-fold, phosphate rose 5-fold, and potash 9-fold.[3]

Changes in competitive structure have also taken place in the fertilizer industry. Before World War II, only seven firms manufactured anhydrous ammonia in the United States, with the two largest firms accounting for 87 percent of production. By 1970 more than 85 firms produced

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[2] Lauth, James H. and Sammartino, Rebecca S., "Problems and Issues in Agricultural Transportation," Paper presented to NC-11 Rural Transportation Seminar in Kansas City, Missouri, May 6, 1975, states that, "Railroads are estimated to use 670 BTU's per intercity freight ton mile. This compares with 450 BTU's for pipelines, 860 for inland water vessels and 2800 for trucks."

[3] Economic Research Services, "U.S. Department of Agriculture, United States and World Fertilizer Outlook - 1974 and 1980." Agricultural Economic Report - No. 257 - May, 1974, Pg. 1.

anhydrous ammonia and only 18 percent of the production was accounted for by the four largest firms.[4] Introduction of the centrifugal compressor for producing nitrogen in the late 1950's was a major contribution to industry growth. A strong demand for chemical fertilizers was also an important growth factor.

Chemical fertilizer use in the United States has increased from 24,877,000 tons in 1960 to 42,536,000 tons in 1973--an increase of 71 percent in 13 years.[5] An approximate annual increase of 4 percent compounded for a seven-year period beginning in 1974 would increase quantity of fertilizer demanded in 1980 over 1973 by nearly 38 percent. Identification of patterns of interregional transportation movement and projected transport needs by mode of transport will aid in planning transport facilities for efficient distribution.

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[4] Ibid, Pg. 2.

[5] Ibid, Pg. 3.

CHAPTER II

Study Objectives and Procedures

Relatively little is known about patterns of delivery of agricultural fertilizers. However, fertilizer transport is reported to be one of the principal products transported to rural areas by railroads. Delivery cost increases for fertilizer are predicted if rail branch lines are abandoned. Cost increases are also threatened if gasoline prices for motor freight carriers increase sharply.

Fertilizer is distributed in various physical forms pertinent to conditions of transport. Gaseous, liquid or dry bulk fertilizer forms require different types of transport vehicles, have different loading characteristics, and have different carrier cost conditions surrounding their movement. To some extent the quantity of transport to be demanded of various transport modes is related to differences in use trends by types of fertilizer.

Objectives of this study relate to the identification of interregional transport demand for movement of fertilizer to a region of Kansas and the projection of an expected transport demand pattern to 1980.

More specific objectives are: (1) to determine the present interregional transportation inputs into wholesale distribution of fertilizer in the North Central Crop Reporting District of Kansas; (2) to relate the estimates of fertilizer use in 1980 in the North Central Crop Reporting District to estimates of transportation requirements by mode

with cost minimizing mode combinations and (3) to determine changes in modal split in fertilizer transportation use for the district for 1980 assuming varying levels of railroad transport rates.

Analytical Procedures

Analytical procedures for this study were designed to: (1) provide base data to describe patterns of fertilizer use and distribution in the study area, (2) formulate a fertilizer transport least-cost network for delivery of fertilizer in 1980 to dealers in the study area, (3) determine transportation configuration at least-cost to shippers under railroad rate strategies deviating from full cost.

Secondary data did not provide adequate information to estimate volume of fertilizer movement to the study area by type of fertilizer or by mode of transportation used. Data on fertilizer delivery to the study area were obtained by interview survey of a 25 percent random sample of retail fertilizer dealers. The dealer sample was selected from a list of all dealers provided by the Kansas Fertilizer and Chemical Institute. Shipment records were recorded for a five-year period, 1970 through 1974. Major objectives of the survey were to learn: (1) the amounts and kinds of fertilizer presently used in the study area, (2) trends in fertilizer use in the period 1970 through 1974, (3) origins of fertilizer entering the study area and (4) transport modes and mode combinations used in movement of fertilizer. Organizational characteristics of all firms responding to the questionnaire were also obtained during the interviews.

Transportation costs were determined by mode from each origin to each destination as applicable. A minimum cost pattern for transportation of fertilizer products in 1980 was determined based on rail rates

and service rates for carriers in 1974. Various levels of railroad rates based on rail cost characteristics were subsequently applied to the transportation model to determine modal shifts and changes in distribution patterns.

Data for determination of transportation costs were obtained from shipper and carrier sources. Cost data characteristics and limitations will be discussed in a later chapter. Statistical models used in the estimation of transport costs and in determination of the minimum cost transportation configuration were a network routing model and a transportation linear programming model.

The network routing model is a scientific procedure for solving problems in sequential programming (Figure 1). In this study it was used to determine the shortest distance highway and railway short-line mile networks. This was accomplished by using the major fertilizer supply points identified in the survey as origins and study area county seats as destinations. Separate networks were constructed for highway and for railway miles.

Highway miles were developed by identifying and numbering each origin and destination served by a highway system. The network was developed by pairing each origin and each destination. Distances between each pair were recorded using the Household Movers Guide Maps as a mileage reference. The only restriction placed on this procedure was that no origin or destination could be connected by passing through another origin or destination. For example, if points A, B and C are all on the same roadway, points A and B, and B and C must be connected separately so as to establish the mileage between points A and C. The railroad network was developed in the same manner, using Kansas Cooperation Commission (K.C.C.) railroad maps as a mileage reference. Shortest-distance

highway and railway networks were determined by the network distribution computer program. When computing the minimum distance with the network model between all origin points (J = 1,2...M) and destination points (I = 1,2...N) the number of minimum distances required is:

R = M * N, where

R = number of minimum distances

M = number of origins

N = number of destinations

The minimum-cost routing problem requires an extension of the ideas used in the network model. For example, if there is only one origin and several destinations, the distance (D) must be computed from that origin to each destination i.e., Dji for i=1,2...N to the origin point. The route from one origin to one destination can be either direct or indirect by way of intermediate modes. If indirect the distance would simply be an addition of links from the origin to the destination. This information was then integrated with the transportation linear programming model.

In this study the transportation linear programming model was used to determine the minimum cost fertilizer distribution system using intermodal transport combinations. The model is a by-product of World War II research designed to solve logistical problems of troop, supply and equipment movement. The linear programming method is essentially a method of solving simultaneous equations and inequations for an optimum solution.

Mathematically defined, this model, with a minimization objective subject to linear restraints, may be stated as follows:

$$\text{Minimize } C = \sum_i \sum_j C_{ij} X_{ij} \text{ where} \qquad (4.2)$$

$$i = 1,2 \ldots\ldots N$$

$$j = 1,2 \ldots\ldots M$$

Subject to constraints:

$$\sum_j X_{ij} = S_i \qquad (4.3)$$

$$\sum_j X_{ij} = R_j \qquad (4.4)$$

$$X_{ij} = 0$$

$$\sum_{i=i}^{M} Si = \sum_{j=i}^{N} Rj \qquad (4.6)$$

Where:

- C is the cost of all operations.
- M is the number of demand points.
- N is the number of supply points.
- S_i is the quantity of a commodity supplied at the i^{th} location.
- R_j is the quantity of the commodity demanded at the j^{th} location.
- C_{ij} is the transfer cost of the commodity to location j.
- X_{ij} is the quantity of commodity shipped from S_i to R_j such that the costs of the operation are minimized.

Equations (4.3), (4.4) and (4.6) are represented in Figure 1.

	Destinations						
	1	2	.	.	.	N	S_i
1	C_{11}	C_{12}	.	.	.	C_{1N}	S_1
2	C_{21}	C_{22}	.	.	.	C_{2N}	S_2
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
M	C_{M1}	C_{M2}	.	.	.	C_{MN}	S_M
R_j	R_1	R_2	.	.	.	R_N	

Figure 1 Transportation Matrix

There are N demand points receiving product from M potential suppliers when the system is read by columns from top to bottom. There are M * N elements in the matrix, and each element has a corresponding cost element, C_{ij}. Equation 4.6 is satisfied when the R_j row total and the S_i column total are equal. A slack origin or destination can be added if R_j and S_i are not equal.

Once the cost per unit of distance is determined, the distance can be multiplied by the cost per unit of distance to determine the delivery cost of fertilizer for the supplier for each possible route.

The network analysis was employed to determine the minimum distance from each origin to each destination. This was done for both roadway and railway systems. Once the networkds were developed, the next step was to develop delivery cost estimates per ton mile of each mode of

transport. Various transport cost data are presented in Chapter VI. Since barge and pipeline fertilizer movements are restricted by their geographic locations, the cost estimates per ton for these modes were added on as a transhipment charge to origins being served by them.

Since the demand and supply quantities have been determined and the minimum distance between all origins and all destinations have been determined, the cost per ton-mile by mode of transport can be applied to these distance traces thus composing the cost matrix for the linear programming model. The constraints are the quantities supplied at each origin and the quantities demanded at each destination.

Transport costs used in this model were based upon data supplied by shippers, private carriers and published government reports. Fertilizer estimates for 1980 were developed in a previous study prepared for Corps of Engineers, Tulsa District, Department of the Army.[6]

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[6]Phillips, Richard; Sorenson, Orlo; and Schruben, Leonard, "How Extending River Navigation into Kansas and Central Oklahoma Would Affect Transportation Costs of Fertilizer." Department of Agricultural Economics, Agricultural Experiment Station - Kansas State University - 1974.

CHAPTER III

The Study Area

The study area is an eleven county area in North Central Kansas. The eleven-counties comprise the Kansas North Central Crop Reporting District as illustrated in Figure 2. In 1973, farmers in the area harvested 1,131,000 acres of wheat; 796,000 acres of sorghum and 144,000 acres of corn. Also, in 1973, 190,000 acres in the study area produced alfalfa hay; 90,000 produced other hay and 2,085,000 acres were in pasture (Table 1.) Total area in the eleven counties is 8,194 square miles (5,504,151 acres). Approximately 2,400,000 acres of grain crops, fodder or hay are harvested each year. The eastern counties (Washington, Clay, Republic, Cloud, Ottawa and Mitchell) report larger percentages of harvested acres than the remaining seven counties.

The study area is served by five rail companies (Figure 3). The area contains 745 miles of roalroad track, 143 miles (19%) of which is main line and 602 miles (81%) is branch line. Rail lines in the area are low traffic density lines except the Rock Island line which crosses the northern counties through Mankato and Smith Center, entering Nebraska just east of the Republic/Washington county line; the Rock Island line southeast from Belleville through Clay Center; and the Missouri Pacific line east from Concordia in the direction of St. Joseph, Missouri. All other line is in Federal Railroad Administration tonnage class 1 (0 to .99 millions of gross ton miles per mile annually). The section of

Missouri Pacific line east of Concordia is in tonnage class 2 (1 - 4.99 millions of gross ton miles per mile) and the Rock Island line listed above is in tonnage class 3 (5 - 9.99 millions of gross ton miles).

The area also contains important mileage that is low capacity track. Area rail mileage rated under 263,000 pounds capacity on a four wheel vehicle are the Santa Fe lines from Barnard to Manchester (43 miles); Missouri Pacific lines from Washington to Greenleaf (7 miles) and Lenora to Downs (85 miles); the Union Pacific lines from Beloit to Solomon (57 miles) and the line across Rooks county and the Southwest corner of Osborne county (47 miles); and the Burlington Northern line from Concordia north to the Nebraska state line (65 miles). Total low capacity line is 304 miles or more than 40 percent of total miles of track in the area.

Low capacity line railroads face the alternative of: (1) high operating costs because the line will not accommodate modern equipment at normal operating speeds, (2) capital expenditure to upgrade lines, or (3) abandonment of line. Estimates of traffic potential on these lines will aid in the determination of the future for low-capacity lines. Such estimates for fertilizer would be made combining routings with rail volume estimates contained in this study.

The study area is served by several Federal, State and County highways (Figure 4). The area is crossed in east-west directions by U.S. Highways 24 and 36 and in north-south directions by U.S. Highways 81, 183 and 281. Eight State highways (Nos. 8, 9, 14, 15, 18, 28, 128 and 148) serve the area. In addition, the interconnecting system of local roads contributes to a system of very adequate road mileage in the area.

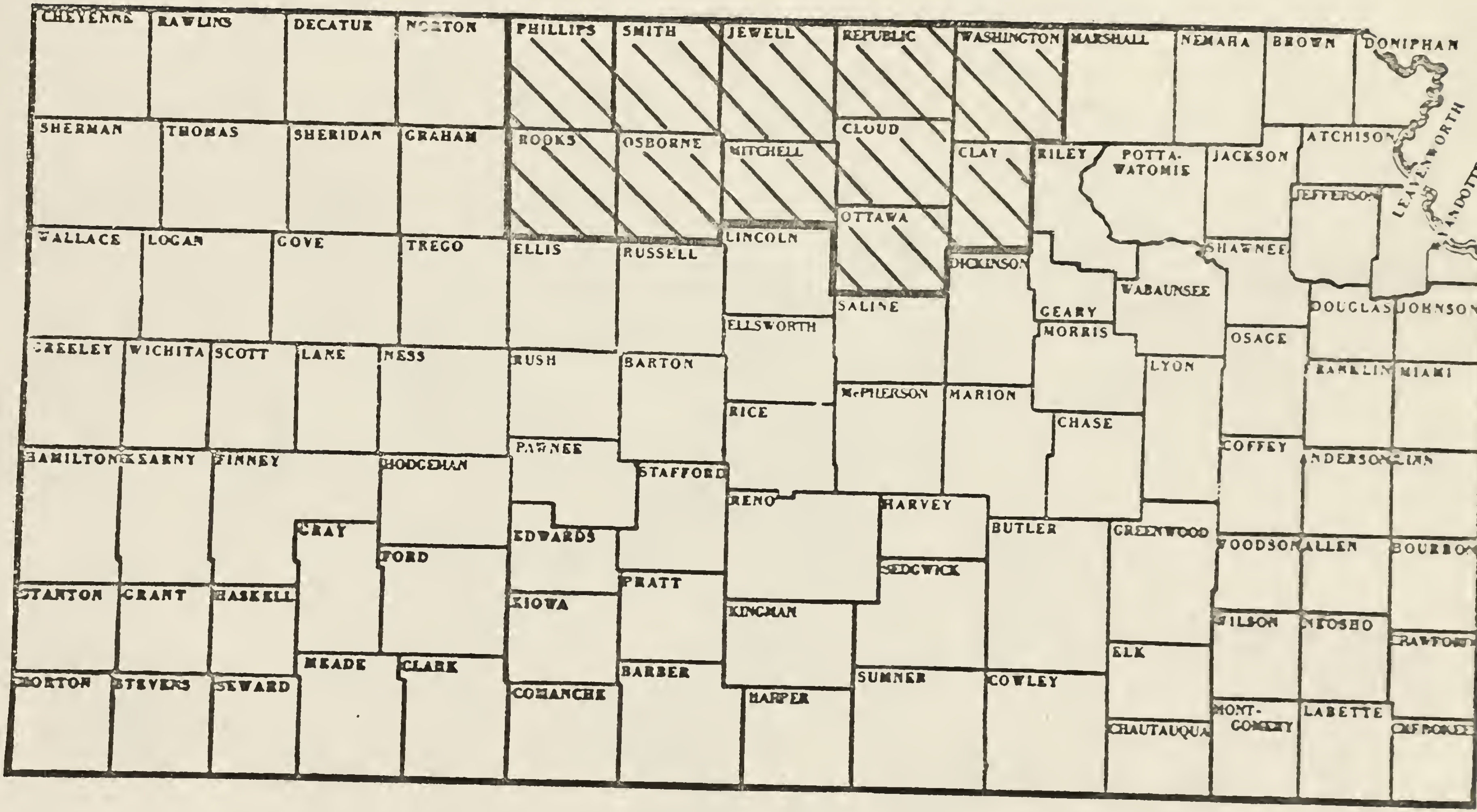

Figure 2 Study Area in Relation to the State of Kansas

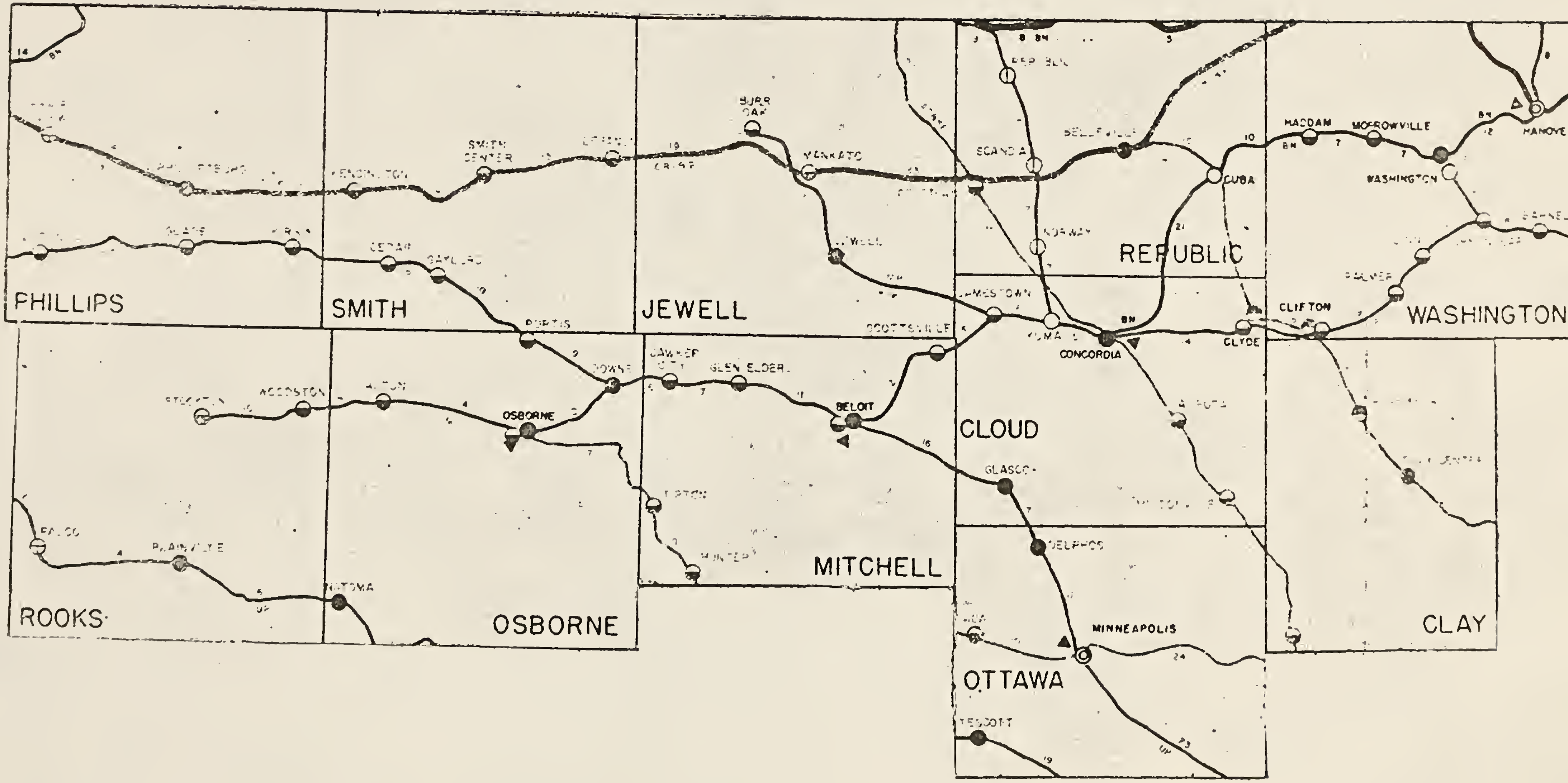

Figure 3 Railway System Serving the Study Area

Table 1. Harvested Acres by Crop by County in North Central District, Kansas - 1973

	Wheat	All Sorghum	Corn	Soybeans	Barley	Oats	Alfalfa Hay	Other Hay	Total
North Central District									
Clay	81,000	83,300	15,000	3,900	100	1,100	16,100	11,700	212,200
Cloud	112,000	67,900	13,700	1,900	290	1,430	17,600	7,400	222,220
Jewell	102,000	86,200	13,400	1,200	480	580	20,000	9,600	233,460
Mitchell	143,000	66,000	3,900	1,500	190	480	10,500	7,500	233,070
Osborne	116,000	48,900	4,900	680	290	560	11,900	8,300	191,530
Ottawa	130,000	34,000	4,900	1,800	380	640	16,200	6,200	194,120
Phillips	83,000	60,800	5,700	*	190	430	24,500	6,700	181,320**
Republic	80,000	85,400	49,100	3,900	190	1,680	16,400	8,900	245,570
Rooks	118,000	35,200	1,900	*	190	320	14,400	5,600	175,610**
Smith	99,000	85,600	9,800	*	380	1,360	19,200	8,000	223,340
Washington	67,000	143,100	22,100	4,400	100	2,000	23,200	19,500	281,400
Total for Dist.	1,131,000	796,400	144,400	19,480	2,780	10,580	190,000	99,400	2,394,040***

Source: Fifty-seventh Report, Kansas State Board of Agriculture, 1973 - 74.
Kansas Statistical Abstract, 1973 - Institute for Social and Environmental Studies, University of Kansas, Lawrence, Kansas.

* Counties having a harvested acreage of less than 200 acres of soybeans are not shown separately, but are included in district totals.

** Figures do not include soybean acreages for Phillips and Rooks counties.

*** Sum of Total for District includes *soybean acreage for Phillips and Rooks counties not listed in the table.

Table 2. Total Crop and Pasture Acres by County in the North Central District - 1973.

	Total Acres/County	Percent of Acres Cropland	Total Acres Pastureland* (1000 Acres)	Percent of Acres Pastured
North Central District				
Clay	406,480	52.0	133	25.3
Cloud	439,220	50.6	143	32.5
Jewell	560,299	41.7	197	35.1
Mitchell	442,309	52.7	128	28.9
Osborne	554,740	34.5	260	46.8
Ottawa	446,633	43.5	175	39.1
Phillips	559,681	32.4	260	46.5
Republic	444,162	55.3	120	27.0
Rooks	548,562	32.0	231	42.0
Smith	551,650	40.5	228	41.3
Washington	550,415	51.1	210	38.1
Total for District	5,504,151		2,085	

Source: Fifty-seventh Report, Kansas State Board of Agriculture, 1973 - 74.
Kansas Statistical Abstract, 1973, Institute for Social and Environmental Studies, University of Kansas, Lawrence, Kansas.

* 1969 U.S. Census of Agriculture adjusted to all farm basis.

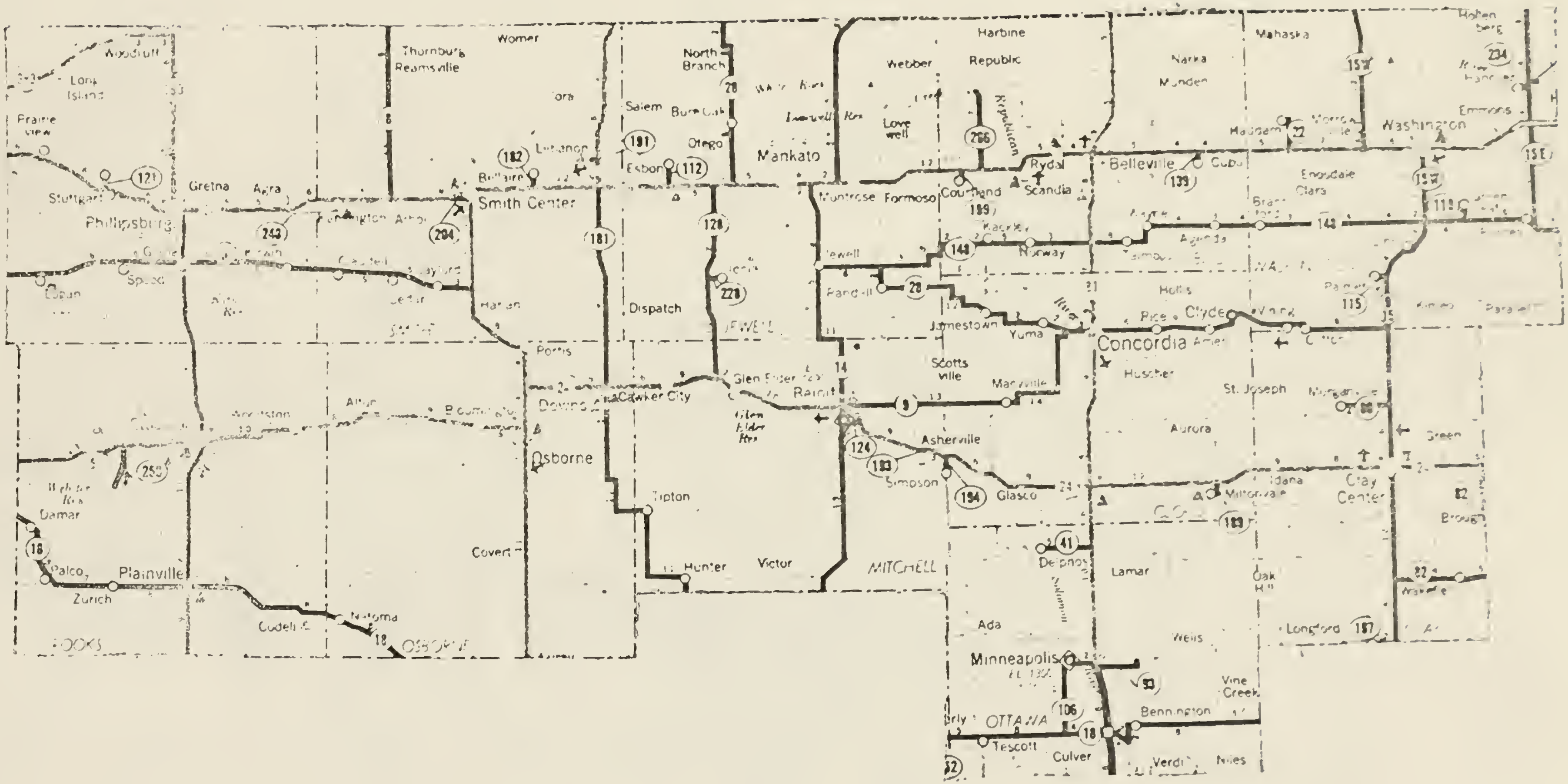

Figure 4 Roadway System Serving the Study Area

Mid-America pipeline company (MAPCO) operates an anhydrous ammonia pipeline through the eastern portion of the study area with a terminal facility for delivery of fertilizer at Clay Center in Clay County. The pipeline delivers anhydrous ammonia from processing plants at Borger, Texas, and Enid, Oklahoma (Figure 5).

The Mississippi River system provides a traffic way for bulk raw materials, including fertilizer (Figure 6). A study by the Farmer Co-operative Service indicates the fourteen (14) regional grain cooperatives in the Midwest received over 367,000 tons of fertilizer by barge in 1970.[7] Ninety-nine percent of that tonnage originated in Louisiana or in Florida with transhipment on river barge at New Orleans. The Missouri River is navigable by river barge equipment from its mouth on the Mississippi to Kansas City, Atchison and points beyond, although tows are smaller and barges must be loaded for shallower draft on the Missouri River channel than on the Mississippi River. Six barge tows at 7 to 7.5 foot drafts are common on the Missouri River. Combined with truck transport from Missouri River ports, the Mississippi-Missouri river movement serves the study area in interregional delivery of fertilizer.

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[7] U.S. Department of Agriculture, Farmer Cooperative Service, Service Report 132, June - 1973.

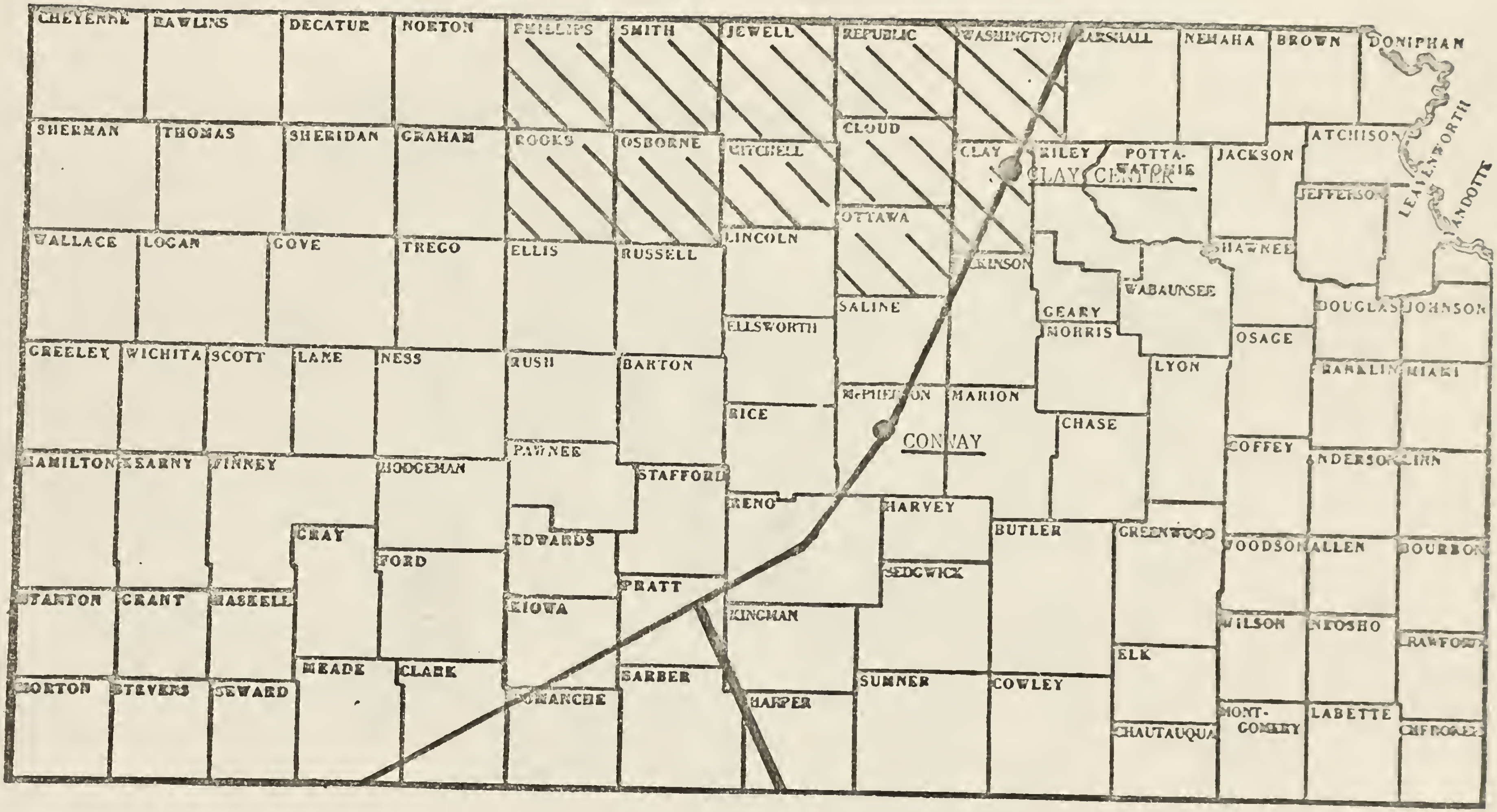

Figure 5 Anhydrous Ammonia Pipeline System Serving the Study Area

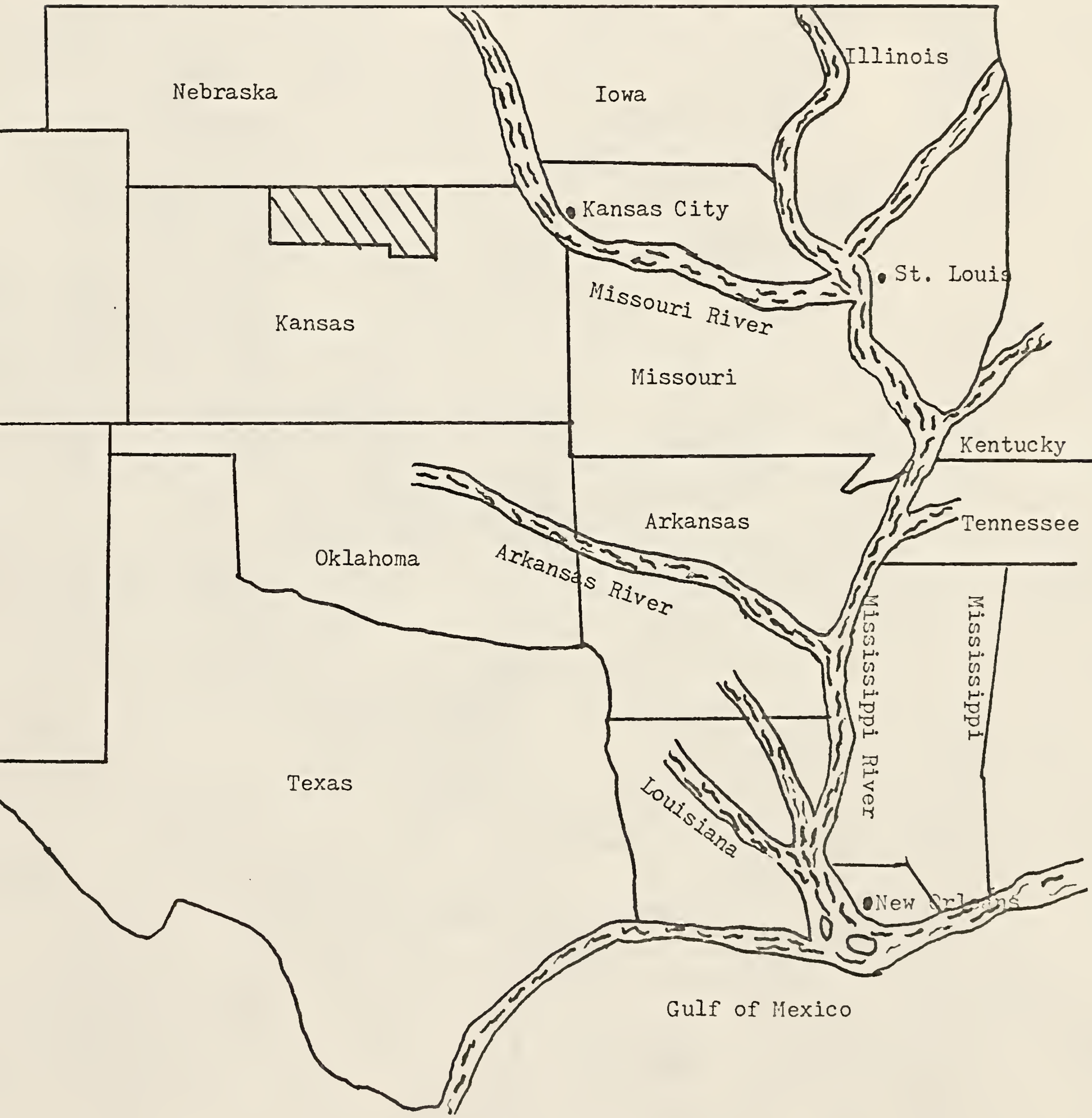

Figure 6 Coastal and Inland Waterways Servicing the Study Area

CHAPTER IV

Dealer Survey

Interviews were held with a 25 percent random sample of all known fertilizer retail dealers in the study area. Participants were selected from a list supplied by the Kansas Fertilizer and Chemical Institute of all fertilizer dealers in the study area. Of the thirty dealers selected, twenty-eight (28) were qualified respondents. One of the firms selected had discontinued its dealership and another was a full time farmer who was erroneously listed as a fertilizer dealer. Distribution by county of the dealers interviewed was as follows: Osborne and Phillips, one each; Ottawa, Republic, Rooks and Smith, two each; Cloud, Mitchell and Washington, three each; and Clay and Jewell counties, four each. The interview questionnaire is illustrated in Appendix A.

Dealer Characteristics:

Dealer ownership was divided fairly evenly among three categories: individual ownership (10 firms); agricultural cooperatives (8 firms) and non-cooperative corporations (10 firms). Interview data established that 23 percent of fertilizer distributed in the study area was sold by individually-owned firms, 35 percent by farmer cooperative associations and 42 percent by non-cooperative corporations. Hence, individually owned firms handled a slightly smaller average annual volume than either the cooperative or non-cooperative corporations.

Dealers characteristically operated other businesses. The majority of the dealers (nineteen) operated a grain elevator in conjunction with their fertilizer dealership, three dealers handled fertilizer and other farm supplies and six specialized in fertilizer sales and service only. Seven of the dealers combining fertilizer dealerships with a grain elevator also handled additional farm supplies. Dealerships combined with grain elevator operations handled 73 percent of fertilizer sold in the study area in 1974

Fertilizer Deliveries:

Fertilizer receipts and conditions of delivery were recorded from completed questionnaires for the five year period 1970 through 1974. Mode utilization by product form determined from the survey is shown in Tables 3, 4 and 5. As indicated in Table 3, anhydrous ammonia is primarily received at dealer facilities by truck, with a five-year average of 94 percent truck movement and 6 percent rail movement. Truck shipments also dominate liquid fertilizer movements with a five-year average of 83 percent of dealer receipts by truck and 17 percent by rail (Table 4). A five year average of dry bulk fertilizer movements to wholesale dealers in the study area indicates that rail service is the primary mode, with 75 percent of total volume by rail and 25 percent by truck (Table 5).

Summaries of estimated volume of deliveries terminated by county destination and by origin and mode of transportation for dealers in the survey sample are shown in Table 6 for anhydrous ammonia; in Table 7 for liquid fertilizer; and in Table 8 for dry bulk fertilizers. Origins recorded are those of shipment by the mode of final delivery. Conway and Clay Center, Kansas, are served by anhydrous ammonia pipeline and

subsequent deliveries from those points (and others) involve a combination of truck and pipeline or rail and pipeline delivery to a more distant point.

From the origin points indicated in Table 6, 7 and 8 major origins were selected for later use in the transportation linear programming model. For anhydrous ammonia the points were: Enid, Oklahoma and Borger, Texas with transhipment points at Conway and Clay Center, Kansas. Other origins were: Dodge City, Lawrence and Wichita, Kansas and Hastings, Nebraska. These origins or transhipment points combined supplied 88 percent of the anhydrous ammonia delivered to dealers in the study area in 1974. No origin supplied more than 19 nor less than 6 percent of total quantity supplied from all origins.

Table 3. Transportation Mode Utilization Based on Sample Anhydrous Ammonia Receipts by Dealers in the Study Area - 1970 Through 1974.

Year	Number of Dealers Responding	Mode	Tons Received	Percent by Mode
1970	10	Truck	2,554	91
		Rail	260	9
1971	15	Truck	5,975	100
		Rail	0	0
1972	19	Truck	7,017	99
		Rail	80	1
1973	22	Truck	10,477	89
		Rail	1,288	11
1974	22	Truck	9,848	91
		Rail	971	9

Table 4. Transportation Mode Utilization Based on Sample Liquid Fertilizer Receipts by Dealers in the Study Area - 1970 Through 1974.

Year	Number of Dealers Responding	Mode	Tons Received	Percent by Mode
1970	7	Truck	2,130	90
		Rail	240	10
1971	11	Truck	2,243	89
		Rail	270	11
1972	11	Truck	4,417	85
		Rail	798	15
1973	13	Truck	6,657	85
		Rail	1,202	15
1974	17	Truck	6,826	67
		Rail	3,338	33

Table 5. Transportation Mode Utilization Based on Sample Dry Bulk Fertilizer Receipts By Dealers in the Study Area - 1970 Through 1974.

Year	Number of Dealers Responding	Mode	Tons Received	Percent by Mode
1970	13	Truck	1,450	41
		Rail	2,092	59
1971	13	Truck	1,561	22
		Rail	5,211	78
1972	18	Truck	1,492	19
		Rail	5,983	81
1973	21	Truck	1,950	17
		Rail	9,282	83
1974	22	Truck	2,997	25
		Rail	9,188	75

Table 6 Anhydrous Ammonia Shipments Terminated by a 25-percent Sample of Fertilizer Dealers in the Study Area, by Origin, Destination by County Seat in the County Location of Dealers and by Type of Carrier, 1974 (tons)

Destination Origin	Mode	Belleville	Beloit	Mankato	Clay Center	Concordia	Minneapolis	Phillipsburg	Smith Center	Washington	Stockton	Osborne	Totals
Beatrice, Neb.	Truck	111	-	-	100	-	-	-	-	667	236	-	1,114
Beker, Ill.	Truck	-	42	-	-	-	-	-	-	-	-	-	42
Clay Center, Ks.	Truck	-	388	300	79	418	20	-	-	-	-	-	1,205
Conway, Ks.	Truck	171	57	470	-	399	95	-	-	-	-	-	1,192
Davenport, Neb.	Truck	353	-	-	-	-	-	-	-	-	-	-	353
Dodge City, Ks.	Truck	-	60	181	483	340	-	60	322	167	160	224	1,997
Fremont, Neb.	Truck	58	-	-	-	-	-	-	-	-	-	-	58
Hastings, Neb.	Truck	-	443	370	96	58	-	-	392	-	267	78	1,704
Lawrence, Ks.	Truck	-	152	-	114	38	-	-	41	167	78	57	647
McPherson, Ks.	Truck	-	-	-	-	-	20	-	-	-	-	-	20
Wichita, Ks.	Truck	548	-	498	-	432	38	-	-	-	-	-	1,516
Sub-total Truck													9,848
Armorel, Ark.	Rail	-	-	-	300	-	-	-	-	-	-	-	300
Blythville, Ark.	Rail	-	-	-	-	-	180	-	-	-	-	-	180
Conway, Ks.	Rail	-	-	80	-	-	-	-	-	-	-	-	80
Crystal City, La.	Rail	-	-	-	-	-	-	160	-	-	-	-	160
Dodge City, Ks.	Rail	-	-	-	-	-	-	-	74	-	-	-	74
Donaldsonville, La.	Rail	-	-	97	-	-	-	-	-	-	-	-	97
Yazoo City, Miss.	Rail	-	-	80	-	-	-	-	-	-	-	-	80
Sub-total Rail													971
Total Shipments													10,819

Table 7 Liquid Fertilizer Shipments Terminated by a 25-percent Sample of Fertilizer Dealers in the Study Area, by Origin, Destination by County Seat in the County Location of Dealers and by Type of Carrier, 1974 (tons)

Origin \ Destination	Mode	Belleville	Beloit	Mankato	Clay Center	Concordia	Minneapolis	Phillipsburg	Smith Center	Washington	Stockton	Osborne	Totals
Abilene, Ks.	Truck	-	-	-	23	-	-	-	-	-	-	-	23
Aurora, Neb.	Truck	-	-	-	-	-	-	-	-	900	-	-	900
Beatrice, Neb.	Truck	143	-	-	-	-	-	-	-	-	-	-	143
Columbia, Mo.	Truck	-	-	-	-	-	211	-	-	-	-	-	211
Cordova, Ill.	Truck	-	-	118	-	-	-	-	-	-	-	-	118
Davenport, Neb.	Truck	497	-	-	-	-	-	-	-	-	-	-	497
El Dorado, Ks.	Truck	-	-	-	25	-	-	-	-	-	-	-	25
Fremont, Neb.	Truck	-	-	-	-	-	123	-	-	-	-	-	123
Joplin, Mo.	Truck	-	-	-	-	50	-	-	-	-	-	-	50
Kansas City, Ks.	Truck	-	-	-	-	-	129	145	-	-	-	-	274
La Platte, Neb.	Truck	2,375	-	-	-	-	-	-	-	-	-	-	2,375
Lawrence, Ks.	Truck	-	-	-	269	138	99	-	461	-	-	410	1,377
Louisiana, Mo.	Truck	-	-	-	-	-	22	-	-	-	-	-	22
Omaha, Neb.	Truck	-	-	-	-	-	270	-	-	-	-	-	270
Salina, Ks.	Truck	-	-	-	-	-	347	-	-	-	-	-	347
Topeka, Ks.	Truck	-	-	71	-	-	-	-	-	-	-	-	71
Sub-total Truck													6,826
Armorel, Ark.	Rail	-	-	-	1,500	-	-	-	-	-	-	-	1,500
Columbia, Mo.	Rail	-	-	-	-	-	187	-	-	-	-	-	187
Geismare, La.	Rail	594	-	-	-	-	-	-	-	-	-	-	594
Louisiana, Mo.	Rail	-	-	-	-	-	755	-	-	-	-	-	755
Muscle Shoales, Ala.	Rail	-	-	-	50	-	-	-	-	-	-	-	50
Sheffield, Ala.	Rail	-	-	-	50	-	202	-	-	-	-	-	252
Sub-total Rail													3,338
Total Shipments													10,164

Table 8 Dry Bulk Fertilizer Shipments Terminated by a 25-percent Sample of Fertilizer Dealers in the Study Area, by Origin, Destination by County Seat in the County Location of Dealers and by Type of Carrier, 1974 (tons)

Origin \ Destination	Mode	Belleville	Beloit	Mankato	Clay Center	Concordia	Minneapolis	Phillipsburg	Smith Center	Washington	Stockton	Osborne	Totals
Abilene, Ks.	Truck	-	-	-	-	75	-	75	49	-	-	-	197
Atlas, Mo.	Truck	-	-	-	23	-	-	-	-	-	-	-	23
Hilldrith, Neb.	Truck	-	-	-	-	-	-	-	64	-	-	-	64
Joplin, Mo.	Truck	-	-	-	218	23	-	-	-	-	-	-	241
Kansas City, Ks.	Truck	-	-	-	43	345	-	-	-	-	24	-	412
Kawrence, Ks.	Truck	150	-	28	24	1,237	-	-	-	-	23	-	1,462
Marysville, Oh.	Truck	-	8	-	-	-	-	-	-	-	-	-	8
Omaha, Neb.	Truck	-	-	-	-	-	-	-	-	300	-	-	300
Texas City, Tex.	Truck	50	-	-	-	-	-	-	-	-	-	-	50
Wichita, Ks.	Truck	-	-	-	240	-	-	-	-	-	-	-	240
Sub-total Truck													2,997
Abilene Ks.	Rail	-	-	-	-	118	-	-	-	-	-	-	118
Beatrice, Neb.	Rail	-	-	120	-	50	-	-	-	-	-	-	170
Carlsbad, N.M.	Rail	-	-	151	-	-	-	-	-	-	-	-	151
Cherokee, Ala.	Rail	-	50	-	-	-	-	103	-	-	-	-	153
Donaldsonville.La.	Rail	-	-	158	-	-	398	-	-	-	-	-	556
Ft. Madison, Ia.	Rail	-	-	78	-	-	-	-	-	-	-	-	78
Greenbay, Fla.	Rail	-	487	47	465	1,002	-	-	341	-	149	47	2,558

Table 8 Continued

Origin \ Destination	Mode	Belleville	Beloit	Mankato	Clay Center	Concordia	Minneapolis	Phillipsburg	Smith Center	Washington	Stockton	Osborne	Totals
Houston, Tex.	Rail	-	-	-	665	-	-	-	-	-	-	-	665
Hutchinson, Ks.	Rail	-	-	-	100	-	-	-	-	-	-	-	100
Joplin, Mo.	Rail	-	-	-	377	223	-	-	-	-	-	-	600
Kansas City, KS.	Rail	-	-	-	176	-	-	50	-	-	-	47	273
Kingsbay, Ga.	Rail	-	-	50	-	-	-	-	-	-	-	-	50
Lake Charles, La.	Rail	-	-	-	90	-	-	-	-	-	-	-	90
Lawrence, Ks.	Rail	-	-	114	403	94	-	-	73	-	-	-	684
Little Rock, Ark.	Rail	-	-	-	50	-	-	-	-	-	-	-	50
Marseilles, Ill.	Rail	-	-	-	-	-	-	-	95	-	-	-	95
Muskogee, Ok.	Rail	-	-	-	-	-	-	-	-	56	-	-	50
New Orleans, La.	Rail	-	-	-	-	-	-	-	56	-	-	-	56
Pasadena, Tex.	Rail	-	83	-	-	-	-	-	-	-	-	-	83
Pocatello, Lda.	Rail	-	-	-	-	-	250	-	-	-	-	-	250
Salina, Ks.	Rail	-	100	-	-	-	-	-	-	-	-	-	100
Sheffield, Ala.	Rail	-	-	-	-	49	-	-	-	-	-	-	49
Soda Springs, Ida.	Rail	-	-	-	-	-	-	-	96	-	-	-	96
St. Joesph, Mo.	Rail	-	-	-	-	-	-	-	-	-	-	200	200
Tampa, Fla.	Rail	-	-	219	-	175	-	-	-	600	-	-	600
Tulsa, Ok.	Rail	-	-	-	53	-	-	-	-	-	-	-	53
Webb City, Mo.	Rail	-	-	-	359	-	-	-	-	-	-	-	359
Wichita, Ks.	Rail	-	-	187	-	-	-	-	-	-	-	-	187
Woodstock, Tenn.	Rail	-	-	-	158	-	-	-	-	-	-	-	158
Sub-total Rail													9,115
Total Shipments													12,115

Major liquid fertilizer supply points were selected from Table 7. Included are Aurora, Davenport and Beatrice, Nebraska; Lawrence, Kansas; Louisiana, Missouri; Geismare, Louisiana; and Armorel, Arkansas. These origins were 77 percent of total deliveries in 1974, ranging in percentages from 23 to 2 percent. Beatrice, Nebraska with only 2 percent of total origins in 1974 was included because of the record of origins in 1970 through 1973 which averaged 10 percent of total deliveries of liquid fertilizer to the study area.

Major supply points were also selected for dry bulk fertilizers from Table 8. Included are Joplin, Missouri, supplying 7 percent of the sample shipments in 1974; Lawrence, Kansas, 18 percent; Donaldsonville, Louisiana, 9 percent; Houston, Texas, 6 percent; Tampa, Florida, 5 percent, and Greenbay, Florida, 21 percent for a total of 72 percent of the dry bulk fertilizers delivered to dealers in the study area in 1974.

Reported total delivery of fertilizer to the study area in 1974 was 132,392 tons. Total fertilizer use estimated for the study area in 1974 by a previous study[8] was 127,311 tons or about 96 percent of total tonnage estimated from the sample survey. Techniques for projecting fertilizer use to 1980 will be discussed in the next chapter.

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[8]Phillips, Richard; Sorenson, Orlo; and Schruben, Leonard, "How Extending River Navigation into Kansas and Central Oklahoma Would Affect Transportation Costs of Fertilizer." Department of Agricultural Economics, Agricultural Experiment Station, Kansas State University, 1974.

CHAPTER V

Fertilizer Use Estimates

This chapter presents the development of 1980 fertilizer demand projections as developed in an earlier multi-state study prepared at Kansas State University.[9]

Fertilizer Demand Projections:

Projections of demand were generated in the earlier study by use of the Master Projection computer model. This model is designed to fit mathematical regression trends to historical time series data and to estimate future quantities from the historical data. Alternative formulas for fitting the trends and making projections include (1) linear, (2) exponential, and (3) logrithmic. This model also has the capability for fitting the projections to component parts or sub-regions. For example, differing trends in fertilizer use among counties in a crop reporting district determine allocations among counties of projected total consumption for the district. An exponential formulation was used to develop estimates of primary nutrient requirements nitrogen (N), phosphate (P_2O_5) and potasium (K_2O) for 1980 in a study area which included the North Central Crop Reporting District in Kansas. The basic estimating formula was:

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[9] Phillips, Richard; Sorenson, Orlo; and Schruben, Leonard, "How Extending River Navigation into Kansas and Central Oklahoma Would Affect Transportation Costs of Fertilizer," Department of Agriculture Economics, Agricultural Experiment Station, Agricultural Economics, 1970, pp. 19 - 26.

$Q = a + bx^n$, where

Q = projected quantity

a = intercept value at y axis

b = average incremental (annual) change

x = number of years from first year on time series

n = exponent

Projections of 1980 demand for each of these primary fertilizer nutrients were based on the time series 1950 - 1972. Alternative estimates were derived from a shorter historical base period extending from 1961 through 1972. Estimates from each historical series were generated at exponent values ranging from .6 to 1.4 to determine the equation which best fit the historical data.

Estimates based on time series 1950 - 1972 gave the closest results to fertilizer industry projections of primary nutrients. Using 1950 - 1972 data R^2 (correlation coefficient) values for the three primary nutrients consistently increased from exponents .6 to 1.4. In the time series 1961 - 1972 the R^2 for each of the primary nutrients did not follow this pattern as N increased, P_2O_5 and K_2O decreased.

Although the R^2 for P_2O_5 was the only primary nutrient R^2 that was higher in the 1950 - 1972 time series compared to the 1961 - 1972 time series, the difference between the R^2's for N for the two time periods was not significant. Therefore, based on industry marketing projections and the closeness of the R^2's for N and K_2O the time series years 1950 - 1972 was selected for the base from which to make projections.

An exponential increase in rate of fertilizer application cannot continue indefinitely. It was, therefore, necessary to limit the range of years over which the exponential projection would apply. It was hypothesized that an exponential increase would not continue beyond the point in time when all soil nutrients taken from the soil for plant projection are replaced from chemical fertilizer and crop residue sources.

To determine the year in which full nutrient replacement would occur, it was necessary to develop independent estimates of crop acres, crop combinations and yields. Replacement requirements were estimated for grain, silage, forage and stalk and stover based on the time series 1961 - 1972.

Nutrient requirements and nutrient replacement models indicated that full nitrogen replacement from commercial fertilizer and crop residue would occur in 1980. Hence, use of the exponential formula to project expansion in nitrogen use was not extended beyond 1980. Beyond 1980, growth in nitrogen applications reflect only increases in crop acreage and yield. This year was accepted as the optimum level year for all nutrients because of greater availability of phosphates and potash in Kansas soils and a tendency for slower leaching of phosphates and potash than occurs with nitrogen.

For this study, projected use of dry bulk fertilizers was further identified as dry and bulk nitrogen and dry bulk phosphate. Dry bulk phosphate fertilizers used in the study area originate near Tampa and Greenbay, Florida. Dry bulk nitrogen fertilizers originated largely from five plant locations in Texas, Louisiana, Missouri and Kansas. Liquid fertilizer types were combined into a single classification. Anhydrous ammonia constitutes an additional fourth classification. Presented in

Table 9 are the projected fertilizer demands by county for each of the four product groupings.

Table 9. Projected 1980 Fertilizer Demands by County and Product Groupings (Tons)

County	Anhydrous Ammonia	Liquid Fertilizers	Dry Bulk (P)	Dry Bulk (N)
Clay	6,328	3,610	5,253	7,023
Cloud	6,720	904	4,908	6,573
Jewell	3,962	3,225	1,410	1,392
Mitchell	12,103	338	7,107	5,898
Osborne	7,576	757	3,885	3,383
Ottawa	2,413	4,193	2,901	3,124
Phillips	4,624	1,108	1,115	1,747
Republic	8,016	5,941	3,907	7,758
Rooks	854	334	237	161
Smith	5,926	3,055	1,895	1,167
Washington	10,686	6,376	5,965	7,996
Totals	69,208	29,841	38,585	46,210

CHAPTER VI

Cost Data and Assumptions

For the purpose of this study, ton-mile delivery costs for fertilizer were developed for the four major modes of transport: railroad, truck, pipeline and barge.

Railroad Cost Calculations

Rail costs used in this study are based on costs published in Interstate Commerce Statement No. 1C1-72, Rail Carload Cost Scales by Territories for the year 1972[10] (Figure 7). The Interstate Commerce Commission also refers to territories as regions and in this study the terms are synonymous. Rail costs developed in this document are based on application of Rail Form A, reflecting 1972 operations of all Class 1 linehaul railways assigned to one of seven areas. Region IV (southern territory) and Region V (western territory excluding Mountain Pacific and Trans-territory) were employed in this study. Region V costs were used exclusively to calculate dry bulk nitrogen ton-mile delivery costs to the study area because differences in shipment costs between Regions V and VI were very small. Based on the average mileage between demand points in the study area and Houston, Texas (906 miles), Geismare, Louisiana (1072 miles) and Donaldsonville, Louisiana, (1101 miles), incorporating Region VI would increase cost per ton by 1.10 and 0.83 percent between demand points and Houston, Texas; Geismare, Louisiana and Donaldsonville, Louisiana, respectively. Rail mileages are presented in Appendix E.

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[10]Interstate Commerce Commission, Bureau of Accounts, Rail Carload Cost Scales by Territory, 1972 Statement 1C1-72 - Washington, D.C., 1972.

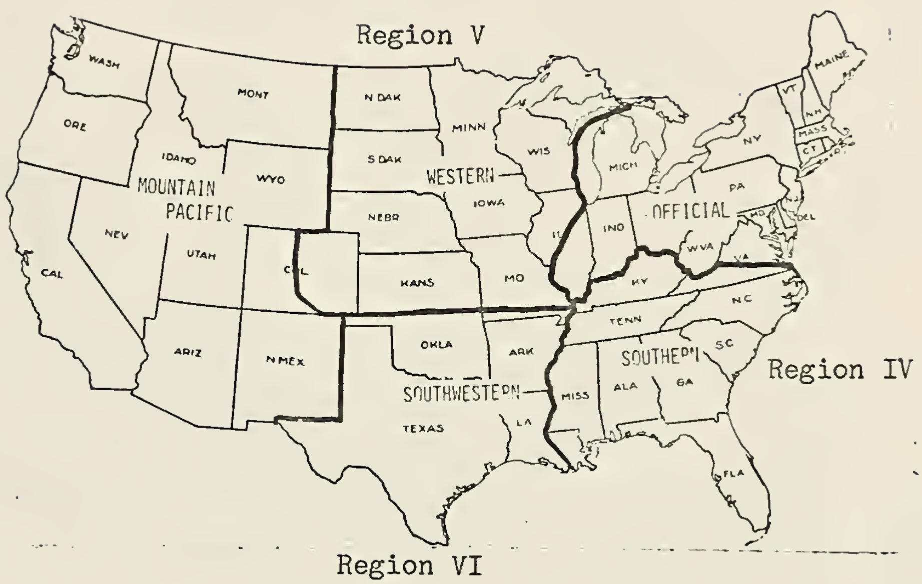

Figure 7. Interstate Commerce Commission Rail Carload Cost Scale Territories

Source: Interstate Commerce Commission, Bureau of Accounts, Rail Carload Cost Scales by Territory, 1972 Statement 1C1-72, Washington, D.C.

Rail costs were developed for three product forms: anhydrous ammonia, liquid fertilizer and dry bulk fertilizer for the relevant regions. Covered-hopper and tank car costs were calculated for the western district, excluding Mountain Pacific and Trans-territory (Region V) and covered-hopper car only in the southern region (Region IV). Only two types of car costs are calculated in this study because anhydrous ammonia and liquid fertilizer utilize the same tank-type cars. For this study, tank car costs were not calculated for Region IV because neither anhydrous ammonia nor liquid fertilizer was reported shipped from that region to study area destination. Examples of cost calculations are presented in Tables 10, 11 and 12.

For the purpose of illustration, cost calculations in Table 10 will be fully explained. Table 10 represents carload costs for a fully-loaded 100 ton (2,000 cwt.) covered hopper-car moving 174 short line miles within Region V.

Variable Costs:

Variable costs (out-of-pocket costs) are separated into three costs groupings: terminal, way-train and through-train. These costs are defined as follows: (1) terminal costs - those costs associated with railroad yards and service facilities; (2) way-train costs - those costs associated with transporting products between way stations (a small railroad station between more important ones where through trains stop only on signal) and (3) through-train costs - those costs associated with transporting products between major railroad stations.

Terminal costs are a combination of carload and hundredweight costs. In the example in Table 10, costs associated with terminal handling of each carload are 5.8376 cents/cwt. (line 1). Additional costs associated

Table 10. Sample Calculation of Carload Unit Costs for 100-ton Load Moving 174 Short-line Miles in a Covered Hopper-car in Region V, United States, 1972.

Covered Hopper Car Costs for Region V		Cost in Cents
Variable Costs:		
1. Terminal: per carload	Table 3, line 8, col. 6	11675.1327
2. per cwt	Table 3, line 8, col. 7	.0413
3. Total per cwt	(line 1 ÷ 2000) + line 2	5.8789
4. Way train: per car-mile	Table 3, line 24, col. 4	45.733
5. per cwt-mile	Table 3, line 24, col. 5	.0204
6. Total per cwt-mile	(line 4 ÷ 2000) + line 5	.0433
7. Through train: per car-mile	Table 3, line 40, col. 4	36.6337
8. per cwt-mile	Table 3, line 40, col. 5	.0129
9. Total per cwt-mile	(line 7 ÷ 2000) + line 8	.0312
10. Mileage total	174	
11. Way train	74	
12. Through train	100	
13. Way train costs	(line 6 x 1.20) x line 11	3.845
14. Through train costs	(line 9 x 1.20) x line 12	3.744
15. Total costs per cwt	Sum of lines 3, 13 & 14	13.4679
Constant Costs:		
16. Terminal costs per cwt	Table 3, line 8, col. 9	3.1671
17. Line haul costs per cwt-mile	Table 3, line 8, col. 8	.0156
. Fully Allocated Costs		
18. Way Train per cwt-mile	(line 6 + line 17) x 1.20	.0707
19. Through train per cwt-mile	(line 9 + line 17) x 1.20	.0562
20. Total terminal costs	line 3 + line 16	9.0406
21. Total way train costs	line 18 x line 11	5.2318
22. Total through train costs	line 19 x line 12	5.620
23. Total costs per cwt	Sum of lines 20, 21 & 22	19.8978
24. Total costs per ton	line 23 x 20	397.956

Source: Interstate Commerce Commission, Bureau of Accounts, Rail Carload Cost Scales by Territory, 1972 Statement 1C1-72, Washington, D.C., pp. 129 - 132.

Table 11. Sample Calculation of Carload Unit Costs for 99-ton Load Moving 174 Short-line Miles in a Tank car in Region V, United States, 1972.

Tank Car 28,000--31,999 Gallons COSTS FOR REGION V			Cost in Cent
Variable Costs:			
1.	Terminal: per carload	Table 3, line 16, col. 6	7642.27
2.	per cwt.	Table 3, line 16, col. 7	.0413
3.	Total per cwt.	(line 1 ÷ 1980) + line 2	3.901
4.	Way train: per car-mile	Table 3, line 32, col. 4	71.5097
5.	per cwt-mile	Table 3, line 32, col. 5	.020[illegible]
6.	Total per cwt-mile	(line 4 ÷ 1980) + line 5	.0965
7.	Through train: per car-mile	Table 3, line 48, col. 4	57.528[illegible]
8.	per cwt-mile	Table 3, line 48, col. 5	.012[illegible]
9.	Total per cwt-mile	(line 7 ÷ 1980) + line 8	.042
10.	Mileage total	174	
11.	Way train	74	
12.	Through train	100	
13.	Way train costs	(line 6 x 1.20) x line 11	[illegible].0122
14.	Through train costs	(line 9 x 1.20) x line 12	5.040
15.	Total costs per cwt.	Sum of lines 3, 13, & 14	13.9582
Constant Costs:			
16.	Terminal costs per cwt.	Table 3, line 16, col. 9	3.1671
17.	Line haul costs per cwt-mile	Table 3, line 16, col. 8	.0156
	Fully Allocated Costs		
18.	Way Train per cwt-mile	(line 6 + line 17) x 1.20	.0865
19.	Through train per cwt-mile	(line 9 + line 17) x 1.20	.0691
20.	Total terminal costs	line 3 + line 16	7.0681
21.	Total way train costs	line 18 x line 11	6.401
22.	Total through train costs	line 19 x line 12	6.910
23.	Total costs per cwt.	Sum of lines 20, 21 & 22	20.3791
24.	Total costs per ton	line 23 x 20	407.582

Source: Interstate Commerce Commission, Bureau of Accounts, Rail Carload Cost Scales by Territory, 1972 Statement 1C1-72, Washington, D.C., pp. 129 - 132.

Table 12. Sample Calculation of Carload Unit Costs for 100-ton Load Moving 158 Short-line Miles in a Covered Hopper-car in Region IV, United States, 1972.

Covered Hopper Car Costs for Region IV		Cost in Cents
Variable Costs:		
1. Terminal: per carload	Table 3, line 8, col. 6	8709.2343
2. per cwt	Table 3, line 8, col. 7	.0307
3. Total per cwt	(line 1 ÷ 2000) + line 2	4.3353
4. Way Train: per car-mile	Table 3, line 24, col. 4	41.8181
5. per cwt-mile	Table 3, line 24, col. 5	.0201
6. Total per cwt-mile	(line 4 ÷ 2000) + line 5	.041
7. Through Train: per car-mile	Table 3, line 40, col. 4	28.0407
8. per cwt-mile	Table 3, line 40, col. 5	.0128
9. Total per cwt-mile	(line 7 ÷ 2000) + line 8	.0268
10. Mileage total	158	
11. Way Train	58	
12. Through Train	100	
13. Way train costs	(line 6 x 1.20) x line 11	2.8536
14. Through train costs	(line 9 x 1.20) x line 12	3.216
15. Total costs per cwt	Sum of lines 3, 13 & 14	10.4549
Constant Costs:		
16. Terminal costs per cwt	Table 3, line 8, col. 9	2.196
17. Line haul costs per cwt-mile	Table 3, line 8, col. 8	.0146
Fully Allocated Costs		
18. Way Train per cwt-mile	(line 6 + line 17) x 1.20	.0667
19. Through train per cwt-mile	(line 9 + line 17) x 1.20	.0497
20. Total terminal costs	line 3 + line 16	6.5813
21. Total way train costs	line 18 x line 11	3.8686
22. Total through train costs	line 19 x line 13	4.970
23. Total costs per cwt	Sum of lines 20, 21 & 22	15.4199
24. Total costs per ton	line 23 x 20	308.398

Source: Interstate Commerce Commission, Bureau of Accounts, Rail Carload Cost Scales by Territory, 1972 Statement 1C1-72, Washington, D.C., pp. 125 - 128.

with weight of the load is only 0.00413 cents/cwt. (line 2). These costs are computed separatelybecause specific costs can be incurred as a result of weight hauled or on a carload basis. Total terminal costs are computed by dividing the cost per carload by the number of hundredweights being shipped, 2,000 cwt. in this example. This converts carload costs(line 1) to hundredweight cost to facilitate totaling of terminal costs (line 1 and line 2) and terminal costs with way and through-train costs calculated on a hundredweight basis. Major way-and-through train costs are reported on a car-mile basis (lines 4 and 7) with additional costs associated with weight reported on a hundredweight basis (lines 5 and 8). Way and through-train costs per hundredweight mile are multiplied by 120 percent of train miles (20 percent circuity) for each type movement to determine hundredweight cost for the designated trip (174 miles). Total variable cost per hundredweight (line 15) is the sum of terminal costs (line 3) plus way-train (line 13) and through-train (line 14) costs. In this example, total variable costs are 13.4679 cents per hundredweight for the 174 mile trip.

Carload cost scales as reported in ICC Statement 1C1-72 report average way and through-train costs per mile within each designated district or territory. Costs reported therefore, are averages over a broad region, in this case in the western district with exclusions as noted and in the southern territory.

<u>Constant Costs</u>:

Constant or fixed costs are separated into terminal costs per hundredweight and line-haul costs per hundredweight mile as reported in the Rail Cost Formula, Rail Form A for 1972. Constant costs are as allocation in a carload basis of all rail costs not covered in variable cost

analysis. These costs include 20 percent of freight operating expense, rents and taxes less carload operating deficits and a return of 4 percent after Federal income taxes on 50 percent of road property.

Fully Allocated Costs:

Fully allocated costs are the summation of variable and constant costs. Way-train and through-train costs per hundredweight mile are calculated by adding variable and constant costs, then adjusting for circuity. Total terminal costs are a summation of variable and constant costs. Total way-train costs are a result of way-train cost per hundredweight mile, multiplied by the number of way-train miles. Total through-train costs are a result of through-train costs per hundredweight mile, multiplied by the number of through-train miles. Fully allocated total cost per hundredweight (line 23) is a summation of lines 20, 21 and 22 (Table 10). This cost figure was then multiplied by 20 in order to change costs from cents per hundredweight mile to cents per ton (line 24).

Since rail cost data is 1972 data, a method was needed to update it to 1974 levels to be current with costs of other modes. The Wholesale Price Index was employed as a guide for updating rail cost data. A rise of 18 percent in wholesale prices for industrial commodities occurred between 1972 and 1974. This increase was applied to 1972 rail cost data to bring applicable costs to current cost levels.

Limitation of Railroad Cost Data:

Variable and constant costs used in the ICC cost scales are not entirely comparable to short-run variable and constant cost concepts in academic use. Variable costs in the ICC scales are those costs that are variable with traffic over the long-run period and at average traffic

densities. Variable costs include an average of 76 percent of operating costs (varying from 44 to 97 percent in various categories of operating costs), plus an allowance for the cost of capital on 50 percent of the road property and 100 percent of the equipment used in road service.

Constant cost is the remaining operating cost, plus an allowance for return to capital on the remaining road property. Allocation of constant cost (approximately 40 percent of total cost in ICC cost scales) to rail traffic on a ton-mile basis for all traffic results in a determination of fully-allocated cost. Fully allocated costs on a ton-mile basis by territory thus result from a great deal of averaging with variable cost more nearly representing long-run marginal cost than short-run average costs.

Several limitations are inherent in rail cost data for analysis of specific hauls. First, costs estimated on a basis of regional averages are not wholly applicable to specific traffic movements. Carload loading characteristics and track or terrain conditions applicable to a specific service are not taken into account.

The second limitation is the assumption of a constant line-haul cost per ton-mile. Rail line-haul costs are generally characterized as increasing at a decreasing rate as length of haul increases, rather than increasing at a constant rate as in application of ICC cost scales. The result is likely an upward bias on longer haul estimated costs and a downward bias on shorter hauls.

The averaging of costs may also place some upward estimating bias on heavy-loading commodities moving in larger volumes. Operating expenses (e.g. wages of operating personnel) are based on average loads and average train size. Costs may, therefore, be over-stated for heavy-loaded commodities moving in 50 car (or longer) trains.

However, limitations as recognized above do not render these cost data invalid for analytical purposes. Rail Form A cost data are frequently used in research studies although with recognized imperfections. A recently published research study sponsored by the Federal Railroad Administration explains the use of ICC cost scales data as follows: "Despite these limitations of the ICC scale, the present study had no alternative source of data for the rail cost analysis since the scales are the most widely accepted and reliable source available for public use."[11] This study also recognizes limitations of the data, however, for purposes of identifying relevant general cost relationships among transport modes, rail cost data used here are the best available.

Truck Cost Calculations

Trucking costs for this study were supplied by an industry source operating in the state of Kansas. Cost estimates were verified by another industry source also operating in the state of Kansas. Trucking costs in this study are average costs per vehicle mile, including empty movement, and are representative of hauls between 100 and 300 miles.

Table 13 presents a breakdown of variable and fixed trucking costs. Since these costs are average vehicle mile costs, total cost of movement determined for a given vehicle size is vehicle mile costs multiplied by number of miles. Hence, total costs are a linear function of distance traveled.

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[11] Baumel, C. Phillip, Drinka, Thomas, Lifferth, Dennis R., and Miller, John J., "An Economic Analyses of Alternative Grain Transportation Systems: A Case Study." Department of Transportation Report No. FRA-OE-73-4, November, 1973.

Other studies have also concluded that trucking costs are a linear function of distance. Assuming that rates charged reflect costs, and they would in a competitive industry, the results found by this author are in general agreement with those found by Orlo Sorenson and Richard Gillaspie when they found that a linear function best fit the reported data when cattle trucking rates were calculated on a hundredweight basis.[12] Linear functions provided the best fit for truck rates applicable to two studies prepared by the U.S. Army Corps of Engineers.[13]

Costs per ton-mile were determined by dividing the maximum capacity of anhydrous ammonia, liquid fertilizer and dry bulk fertilizer trailers into the average cost per vehicle mile. Truck capacities were 21, 24, and 25 tons for anhydrous ammonia, liquid fertilizer and dry bulk fertilizer, respectively. Resulting costs per ton-mile for anhydrous ammonia were $0.0388 liquid fertilizer $0.0340 and dry bulk fertilizer $0.0327. Truck mileages are presented in Appendix D.

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[12] Gillaspie, Richard L., and Sorenson, Orlo, "Cattle Trucking Rates by Kansas Carriers," Department of Agricultural Economics, Agricultural Experiment Station, Kansas State University, Agricultural Economics, Research Report No. 9, 1972, pg. 1.

[13] Schruben, Leonard W., Phillips, Richard and Sorenson, Orlo, "How Extending River Navigation into Kansas, the Mid-Arkansas River Basin, Would Affect Transportation Costs of Wheat," Department of Agricultural Economics, Agricultural Experiment Station, Kansas State University, Agricultural Economics, 1974, pg. 49, and

[13] Schruben, Leonard W., Phillips, Richard and Sorenson, Orlo, "How Extending River Navigation into Kansas and Central Oklahoma Would Affect Transportation Costs of Fertilizer," Department of Agricultural Economics, Agricultural Experiment Station, Kansas State University, Agricultural Economics, 1974, pg. 36.

Table 13. Average Truck and Trailer Costs per Vehicle Mile

	Cents per Mile
Variable Costs:	
Labor	28.79
Fuel	13.34
Oil-Grease	.28
Tires-Tubes	2.77
Uniforms	.12
Maintenance	11.05
Travel-Drivers	3.84
Shop Expense	7.73
Administrative Expense	2.15
Total Variable Costs	70.07
Fixed Costs:	
Taxes	3.24
Insurance	1.01
Depreciation	6.04
Shop Expense	.90
Administrative Expense	.09
Total Fixed Costs	11.28
Total Costs Per Vehicle Mile	81.35

Pipeline Cost Calculations

Pipeline costs for this study were supplied by Mid-America Pipeline, Inc. (MAPCO), and represent daily operating costs per pipeline mile between production points at Enid, Oklahoma, and Borger, Texas, and terminals located at Conway and Clay Center, Kansas. Mid-America Pipeline Company, Inc., presently operates and maintains 844 miles of anhydrous ammonia pipeline spanning from Enid, Oklahoma and Borger, Texas to Garner, Iowa. But, for the purpose of this study, two transhipment points were considered: Conway, Kansas, 293 miles from Borger, Texas and 185 miles from Enid, Oklahoma, a total of 411 miles for the purpose of this study since the two lines merge at a point 27 miles south of

Conway, Kansas, an additional 84 miles from Conway, Kansas or a total of 495 miles for the purpose of this study.

Two 600-horsepower pumps located at Enid, Oklahoma and Borger, Texas, supply the power to transport anhydrous ammonia from its origin to transhipment points located along the pipeline. Presented in Tables 14 and 15 are the miles involved between production points and terminal locations, total investment, investment per pipeline mile, and variable and fixed costs per pipeline mile.

Calculations were made to convert daily operating costs per pipeline mile into costs per ton. This was accomplished by multiplying daily operating costs by 365, then multiplying that amount by miles traveled and dividing by the yearly throughput (600,000 tons). It was determined that the cost of moving anhydrous ammonia to Conway, Kansas, the combined distance of 411 miles is $1.14 per ton, plus a $1.00 per ton transfer charge for a total of $2.14 per ton and to Clay Center, Kansas, a $1.43 per ton, plus the transfer charge for a total of $2.43 per ton for the combined distance of 495 miles. Pipeline miles were combined in the study to compensate for the reverse movement of anhydrous ammonia through the pipeline system, back pumping as it is called by the industry. Back pumping is a common practice given specific supply and demand situations.

Table 14. Daily Operating Costs Per Pipeline Mile from Enid, Oklahoma and Borger, Texas to Conway, Kansas.

Variable Costs:	
Fuel and Power ($1.50/HP)	$1.74
Total Variable Costs	$1.74
Fixed Costs:	
Ad Valorem Tax (1% Investment)	$ .74
Station Maintenance ($15/HP)	.18
Line Maintenance ($100/mile)	.27
Supervision ($500/location)	.01
Communications ($2,500/location)	.05
Corrosion ($8/mile)	.02
Labor	.80
Return on investment	.77
Total Fixed Costs	$2.84
Total Daily Operating Costs Per Pipeline Mile	$4.58
Transfer Charges Per Ton	$1.00

*Distance of 411 miles with investment of $18,064 per mile.

Table 15. Daily Operating Costs Per Pipeline Mile from Enid, Oklahoma and Borger, Texas, to Clay Center, Kansas.

Variable Costs:	
Fuel and Power ($150/HP)	$1.74
Total Variable Costs	$1.74
Fixed Costs:	
Ad Valorem	$ .74
Station Maintenance ($15/HP)	.18
Line Maintenance ($100/mile)	.27
Supervision ($500/location)	.01
Communications ($2,500/location)	.06
Corrosion ($8/mile)	.02
Labor	.96
Return on investment	.77
Total Fixed Costs	$3.01
Total Daily Operating Costs Per Pipeline Mile	$4.75
Transfer Charges Per Ton	$1.00

*Distance of 495 miles with investment of $18,064 per mile.

Barge Cost Calculations

Barge transport costs were determined for the movement of dry bulk fertilizer from Tampa, Florida and New Orleans, Louisiana to Kansas City, Kansas. Hourly ownership and operating costs were established for towboats and barges appropriate for river channels on which fertilizer would be moved. Comparison of Tables 16, 17 and 18 indicate that changes in channel conditions create different transport requirements. For example, one 18,000-ton ocean going barge powered by a 3,200 horsepower tug is utilized between Tampa, Florida and New Orleans, Louisiana with load, unload and fleeting time totaling 144 hours. This contrasts with the equipment required to transport dry bulk fertilizer between New Orleans, Louisiana and St. Louis, Missouri, where 20 barges loaded to approximately 1,187 tons (7' to 7.5' draft) powered by a 5,600 horsepower towboat, with a total of 240 hours loading, unloading and fleeting time are used. Narrowing channel conditions between St. Louis, Missouri and Kansas City, Kansas restricts equipment to six barges of the type utilized on the Mississippi River powered by a 2,400 horsepower towboat with loading, unloading and fleeting time totaling 144 hours.

Since barge movement is usually done in stages because of changing conditions from one waterway to another, costs were estimated for each stage. Tables 16, 17 and 18 present costs from Tampa, Florida to New Orleans, Louisiana; New Orleans, Louisiana to St. Louis, Missouri; and St. Louis, Missouri to Kansas City, Kansas, respectively.

The budgeting format was adapted from U.S. Army Corps of Engineers' Study, "Re-Evaluation of Projected Economics," Supplement to the General Design Memorandum, Tennessee-Tombigbee Waterway, Alabama and Mississippi, Mobile District (Mobile, 1966). Current cost information was obtained from barge companies.

Table 16. Budgeted Dry Bulk Fertilizer Costs Between Tampa, Florida and New Orleans, Louisiana, 1974.

DISTANCE IN STATUTE MILES	540
<u>TUG OR TOWBOAT</u>	
Horsepower	3,200
Towing Speed	
Up	8.6
Down	10.3
Towing Hours, Round Trip	115
Delay Time, Hours	8
Hourly Operating Costs	$126
Tug Line Haul Costs	$15,498
<u>BARGES</u>	
Number in Tow	1
Cargo Tons Per Tow	18,000
Towed Hours	115
Delay Time, Hours	144
Hourly Operating Costs	$65
Barge Line-Haul Costs	$16,835
Tug Plus Barge Operating Costs	$32,333
Line Haul Per Ton	$1.80
Terminal Charges Per Ton	$2.00
Total Costs Per Ton	$3.80

Table 17. Budgeted Dry Bulk Fertilizer Costs Between Louisiana, and St. Louis, Missouri, 1974.

DISTANCE IN STATUTE MILES	1,134
TUG OR TOWBOAT	
Horsepower	5,600
Towing Speed	
Up	4
Down	10
Towing Hours, Round Trip	396
Delay Time, Hours	8
Hourly Operating Costs	$131
Tug Line Haul Costs	$52,924
BARGES	
Number in Tow	20
Cargo Tons Per Tow	23,740
Towed Hours	396
Delay Time, Hours	240
Hourly Operating Costs	$63.20
Barge Line-Haul Costs	$40,195
Tug Plus Barge Operating Costs	$93,119
Line Haul Cost Per Ton	$3.92
Terminal Charges Per Ton	$1.00
Total Cost Per Ton	$4.92

Table 18. Budgeted Dry Bulk Fertilizer Costs Between St. Louis, Missouri and Kansas City, Kansas, 1974.

DISTANCE IN STATUTE MILES	366
<u>TUG OR TOWBOAT</u>	
Horsepower	2,400
Towing Speed	
Up	3.5
Down	10
Towing Hours, Round Trip	142
Delay Time, Hours	8
Hourly Operating Costs	$72
Tug Line Haul Costs	$10,800
<u>BARGES</u>	
Number in Tow	6
Cargo Tons Per Tow	7,122
Towed Hours	142
Delay Time, Hours	144
Hourly Operating Costs	$18.96
Barge Line-Haul Costs	$5,423
Tug Plus Barge Operating Costs	$16,223
Line Haul Costs Per Ton	$2.28
Terminal Charges Per Ton	$1.00
Total Cost Per Ton	$3.28

Barge costs, like pipeline costs, were treated as a transhipment expense in analytical models determining least-cost transportation scenarios. A transhipment charge of $8.20 was added to Kansas City, Kansas movements of dry bulk fertilizer when moved from New Orleans, Louisiana and $12.00 when moved from Tampa, Florida to Kansas City, Kansas.

Barge costs, like truck costs, tend to be linear with distance due in part to changing conditions encountered on different waterways. For example, as presented in Tables 17 and 18, the upstream speed on the Mississippi River is 4 mph compared with 3.5 mph on the Missouri River. There is also a 16,618 ton cargo (14 barge) differential per tow between the two rivers, with the Mississippi River allowing more cargo to be moved in a single tow. If barges were loaded for the Mississippi River part destinations the cargo differential per tow would be greater.

CHAPTER VII

Distribution System Analysis

Transportation analyses were made for three product groupings (anhydrous ammonia, liquid fertilizer and dry bulk nitrogen fertilizer) using the transportation linear programming model presented in Chapter II. Tons of fertilizer shipped and flow patterns were determined assuming 1980 projected fertilizer demands and varying levels of railroad rates. A fourth fertilizer form, dry bulk phosphate, was analyzed using hand calculations. Relatively few origins from which dry bulk phosphate was shipped simplified the distribution of dry phosphates. These analyses of transport patterns are presented in this chapter for each product grouping. Assumptions for these analyses were as follows:

1. Demand for each fertilizer product is estimated for 1980 for each destination. Supply of each product is estimated for each origin, with total supply equaling total demand. With these demand and supply constraints estimated demand can be met from any combination of existing supply points based on optimum lowest cost intermodal combinations of truck and rail services with rail costs enetered in the model at a level equal to fully-distributed costs.

2. Demand and supply constraints as in number one for optimum intermodal combinations of truck and rail services with rail costs entered in the model at a level 20 percent below fully-distributed costs.

3. Demand and supply constraints as in number one for optimum intermodal combinations of truck and rail services with rail costs entered

in the model at a level 40 percent below fully-distributed costs.

ANALYSIS NO. 1

The first objective of this analysis was to compare a cost minimizing flow pattern by mode and by origin/destination combination with actual patterns obtained from survey data for 1974. The second objective was to establish a base intermodal case to which analyses No. 2 and No. 3 could be compared. The third objective was to measure the cost advantages of using combinations of both modes over using either truck or rail services exclusively.

ANALYSIS NO. 2

The objective of this analysis was to determine the effect of reducing rail costs 20 percent on (1) delivery patterns as compared with Analysis No. 1, (2) volume transported by mode as compared with Analysis No. 1 and (3) revenue generated by mode as compared to Analysis No. 1.

ANALYSIS NO. 3

The objective of this analysis was to determine the effects of reducing rail costs 40 percent on (1) delivery patterns as compared to Analyses No. 1 and No. 2, (2) volume transported by mode as compared to Analyses No. 1 and No. 2 and (3) revenue generated by mode as compared to Analyses No. 1 and No. 2.

DRY BULK PHOSPHATE ANALYSIS

The first objective of these analyses was to compare rail transport costs from Greenbay and Tampa, Florida, to Kansas City, Kansas to determine the more economical origin. The second objective was to compare

rail transport costs from Greenbay, Florida to Kansas City, Kansas to barge transport costs from Tampa, Florida to Kansas City, Kansas to determine the more economical mode of transport.

ANHYDROUS AMMONIA ANALYSIS

Seven origins or transhipment points supplying 88 percent of the study areas anhydrous ammonia demands in 1974 were selected for these analyses: Beatrice and Hastings, Nebraska; Clay Center, Conway, Dodge City, Lawrence and Wichita, Kansas. Since Conway and Clay Center, Kansas are supplied by pipeline from Enid, Oklahoma and Borger, Texas, a transhipment charge was added at each location, $2.14 and $2.43 per ton respectively. It was also determined through examination of sample shipment records that neither Enid, Oklahoma, nor Borger, Texas, supply the study area directly through the use of rail or truck service. Thus, they were not evaluated as individual anhydrous ammonia origins for direct truck or rail movement.

ANALYSIS NO. 1

In this analysis limitations were placed on each origin based on the percentage supplied in 1974. For example, Dodge City, Kansas supplied 21.67 percent of the total volume supplied by the seven origins to the study area in 1974. Applying this 21.67 percent against projected 1980 demands, Dodge City's production capacity is constrained to 14,997 tons out of a total of 69,208 tons demanded. The mode selection option to the transportation linear programming model was also applied. Numbers were assigned each mode, 98 for rail transport and 99 for truck transport.

Presented in Table 19 is the optimum distribution system using intermodal combinations of rail and truck services. Evaluation of this

Table 19. Anhydrous Ammonia Distribution System Assuming Production Capacities Based On Percentage Supplied in 1974 From Seven Major Supply Origins and Combination of Rail and Truck Services With Fully Distributed Rail Costs.

Origin	Destination	Quantity (Tons)	Unit Cost ($/Ton)	Total Cost (Dollars)	Mode [1]
22	1	2270	2.87	6514.90	99
30	1	2399	3.40	8156.60	99
31	1	3347	5.46	18274.62	99
31	2	132	5.19	685.08	99
32	2	11971	6.40	76614.40	99
33	3	3962	3.30	13074.60	99
30	4	6328	1.04	6581.12	99
31	5	3320	4.76	15803.20	99
34	5	3400	5.66	19244.00	99
31	6	2413	3.44	8300.72	99
32	7	2172	6.44	13987.68	99
33	7	2452	4.07	9979.64	99
33	8	5926	2.91	17244.66	99
22	9	5800	1.82	10556.00	99
26	9	4886	5.41	26433.26	98
32	10	854	5.55	4739.70	99
34	11	7576	3.80	28788.80	99
Total		69208		284,978.98	

1. 98 - Rail Service

   99 - Truck Service

table indicates that rail service (98) received 7.06 percent (4,886 tons) of the volume and 9.27 percent ($26,433.26) of the revenue. Truck service (99) received 92.94 percent (64,332 tons) of the volume and 90.73 percent ($258,545.72) of the revenue. Total transport costs to the study area equalled $284,978.98. Table 3 indicates 9 percent rail utilization in 1974 for the transport of all anhydrous ammonia to the study area while truck transport utilization was 91 percent. Rail utilization was lesser in the model than was indicated by sample shipment records and truck utilization was slightly greater in 1974 than optimum as indicated by the linear programming model, but the results were very close. These differences may result from (1) rates not totally representative of carrier costs or (2) an analytical model which does not explicitly recognize service availability or service quality difference among modes.

Presented in Table 20 is the anhydrous ammonia distribution system developed from sample shipment data using the same origins selected for the model, compared to the anhydrous ammonia distribution system developed through the use of the transportation linear programming model, Table 19. The distribution system developed by computer model utilizes fewer origin/destination combinations to distribute anhydrous ammonia than were reported in the dealer survey. Dealers surveyed averaged 3.82 origins per dealer while the model averaged 1.55 origins for each destination. This is to be expected since sample shipment data represents real world situations reflecting price and timely availability of fertilizer from various sources whereas the model sets up a single criteria (transport cost) as the controlling basis for determining the distribution pattern for fertilizer.

Table 20. Sample Anhydrous Ammonia Shipments Compared to the Anhydrous Ammonia Distribution System Presented in Analysis No. 1, (Table 6 Compared to Table 19).

Sample Shipment Data			The Model		
Origin	Destination	Mode [1]	Origin	Destination	Mode [1]
22	1	99	22	1	99
31	1	99	30	1	99
34	1	99	31	1	99
26	2	99	31	2	99
30	2	99	32	2	99
31	2	99			
32	2	99			
33	2	99			
30	3	99	33	3	99
31	3	99			
31	3	98			
32	3	99			
33	3	99			
34	3	99			
22	4	99	30	4	99
26	4	99			
30	4	99			
32	4	99			
33	4	99			
26	5	99	31	5	99
30	5	99	34	5	99
32	5	99			
33	5	99			
34	5	99			
30	6	99	31	6	99
31	6	99			
34	6	99			
32	7	99	32	7	99
			33	7	99
26	8	99	33	8	99
32	8	99			
32	8	98			
33	8	99			
22	9	99	22	9	99
26	9	99	26	9	98
32	9	99			
22	10	99	32	10	99
26	10	99			
32	10	99			
33	10	99			
26	11	99	34	11	99
32	11	99			

1. 98 - Rail Service

   99 - Truck Service

Another comparative analysis was made between sample shipment data and a computer model determined anhydrous ammonia distribution system using the same constraints presented in Table 19, except that rail service was not allowed to enter the model. In this case, total cost of transporting anhydrous ammonia increased by 1.21 percent. Since 1974 sample shipment data indicate that only 9 percent of the anhydrous ammonia shipments between origins and destinations selected for this study were made by rail and 7.06 percent in the computer model (Table 19). It can be concluded that other things equal increased rail shipments at cost related carrier rates would not lead to decreased transport costs to the study area.

Another comparative analysis was also made between sample shipment data and a modeled anhydrous ammonia distribution system using the same constraints presented in Table 19, except truck service was not allowed to enter the model. Total transport costs were increased 36.31 percent over the earlier analysis in which both modes participated in the traffic.

ANALYSIS NO. 2

In this analysis the limitations are the same as presented in Analysis No. 1 with the exception of rail costs which are reduced 20 percent to reflect approximately one-half of allocated fixed costs in determination of fully-distributed costs. The mode selection option was also used in this analysis.

The prupose of this analysis was to determine what effect reducing rail costs to a point where approximately one-half of the fixed costs are recovered would have on competition between rail and truck services (Table 21). A comparison between Tables 19 and 21 indicates a shift in the distribution system to increased rail utilization. Rail shipments

Table 21. Anhydrous Ammonia Distribution System Assuming Production Capacities Based on Percentage Supplied in 1974 from Seven Major Supply Origins and Combinations of Truck and Rail Services With Rail Costs Reduced 20 Percent.

Origin	Destination	Quantity (Tons)	Unit Cost ($/Ton)	Total Cost (Dollars)	Mode [1]
26	1	4669	5.22	24372.18	98
31	1	895	5.46	4886.70	99
33	1	2452	4.54	11132.08	99
32	2	9519	6.40	60921.60	99
34	2	2584	5.19	13410.96	98
33	3	3962	3.30	13074.60	99
30	4	6328	1.04	6581.12	99
31	5	5904	4.76	28103.04	99
34	5	816	5.15	4202.40	98
31	6	2413	3.44	8300.72	99
32	7	4624	6.44	29778.56	99
33	8	5926	2.91	17244.66	99
22	9	8070	1.82	14687.40	99
26	9	217	4.33	939.61	98
30	9	2399	2.36	5661.64	99
32	10	854	5.55	4739.70	99
34	11	7576	3.80	28788.80	99
Total		69208		276,825.77	

1. 98 - Rail Service

   99 - Truck Service

increased from 4886 tons in Analysis No. 1 to 8286 tons in Analysis No. 2, (41.03 percent increase). Truck shipments decreased from 64,322 tons in Analysis No. 1 to 60,922 tons in Analysis No. 2 (5.58 percent increase).

A shift in revenue also occurred as a result of reducing rail transport costs. Rail revenue in Analysis No. 1 totalled $26,433 while in Analysis No. 2 it increased to $42,925 (38.42 percent increase). Truck transport revenue in Analysis No. 1 totalled $258,546 while in Analysis No. 2 it decreased to $233,901 (10.54 percent decrease). This comparison indicates that a 20 percent decrease in rail costs could result in a rail revenue increase of 41.03 percent. Presented in Table 22 are the shifts in origin and mode utilization resulting from a 20 percent reduction in rail costs. Total transport cost to the study area equalled $276,825.77 a decrease of 2.94 percent from Analysis No. 1.

ANALYSIS NO. 3

In this analysis the limitations are the same as presented in Analysis No. 1 with the exception of rail costs which are reduced 40 percent to reflect only out-of-pocket costs being recovered by the railroads.

The purpose of this analysis was to determine what effect reducing rail costs to a point where only out-of-pocket costs are recovered would have on competition between rail and truck services, Table 23. A comparison of Tables 19, 21 and 23 indicates a further shift towards rail service. Rail shipments increased to 27,056 tons (69.37 percent above Analysis No. 2 and 81.94 percent above Analysis No. 1). Truck shipments decreased to 42,152 tons (44.53 percent below Analysis No. 2 and 52.59 percent below Analysis No. 1). Presented in Table 24 are the shifts in origin and mode utilization resulting from a 40 percent reduction in rail costs compared

Table 22. Destination, Origin and Mode Shifts Resulting From Rail Costs Being Reduced 20 Percent. (Table 19 Compared to Table 21).

Destination	Original Origin	Original Mode [1]	Origin Change	Mode Change [1]
1	22	99	26	98
1	30	99	31	99
1	31	99	33	99
2	31	99	32	99
2	32	99	34	98
3	33	99	33	99
4	30	99	30	99
5	31	99	31	99
5	34	99	34	98
6	31	99	31	99
7	32	99	32	99
7	33	99		
8	33	99	33	99
9	22	99	22	99
9	26	98	26	98
9			30	99
10	32	99	32	99
11	34	99	34	99

1. 98 - Rail Service

   99 - Truck Service

Table 23. Anhydrous Ammonia Distribution System Assuming Production Capacities Based on Percentage Supplied in 1974 From Seven Major Supply Origins and Combinations of Truck and Rail Services With Rail Costs Reduced 40 Percent.

Origin	Destination	Quantity (Tons)	Unit Cost ($/Ton)	Total Cost (Dollars)	Mode [1]
26	1	4669	2.74	12793.06	98
32	1	3347	6.40	21420.80	98
31	2	6799	4.23	28759.77	98
32	2	5304	5.32	28217.28	98
33	3	3962	3.30	13074.60	99
30	4	6328	1.04	6581.12	99
32	5	3320	5.37	17828.40	98
34	5	3400	3.86	13124.00	98
31	6	2413	3.44	8300.72	99
32	7	2172	6.44	13987.68	99
33	7	2452	4.07	9979.64	99
33	8	5926	2.91	17244.66	99
22	9	8070	1.82	14687.40	99
26	9	217	3.25	705.25	98
30	9	2399	2.36	5661.64	99
32	10	854	5.55	4739.70	99
34	11	7576	3.80	28788.80	99
Totals				245,894.52	

1. 98 - Rail Service

   99 - Truck Service

Table 24. Destination, Origin and Mode Shifts Resulting From Rail Costs Being Reduced From 20 to 40 Percent. (Table 21 Compared to Table 23).

Destination	Original Origin	Original Mode [1]	Origin Changes	Mode Changes [1]
1	26	98	26	98
1	31	99	32	98
1	33	99		
2	32	98	31	98
2	34	99	32	98
3	33	99	33	99
4	30	99	30	99
5	31	99	32	98
5	34	98	34	98
6	31	99	31	99
7	32	99	32	99
7			33	99
8	33	99	33	99
9	22	99	22	99
9	26	98	26	98
9	30	99	30	99
10	32	99	32	99
11	34	99	34	99

1. 98 - Rail Service

   99 - Truck Service

with a 20 percent reduction in rail costs. Presented in Table 25 are the shifts in origin and mode utilization resulting from both a 20 and 40 percent reduction in rail costs compared with the original model in Analysis No. 1. A cost reduction of $30,931 over Analysis No. 2 and $39,084 over analysis No. 1 could also be realized by the study area assuming the railroads are willing to operate on less than fully-distributed costs which is a common practice by railroads given specific hauls and particular competitive situations.

A further shift in revenue also resulted from reducing rail costs 40 percent. Rail revenue increased to $122,849 (65.06 percent above Analysis No. 2 and 78.48 percent above Analysis No. 1). Truck revenue decreased to $123,046 (90.09 percent below Analysis No. 2 and 110.12 percent below Analysis No. 1).

LIQUID FERTILIZER ANALYSIS

Eight origins supplying 78 percent of the quantity of liquid fertilizer demanded in 1974 were selected for these analyses: Armorel, Arkansas; Aurora, Davenport, Beatrice and LaPlatte, Nebraska; Geismare, Louisiana; Lawrence, Kansas; and Louisiana, Missouri. Code numbers of the liquid fertilizer origins are presented in Appendix B.

ANALYSIS NO. 1

In this analysis limitations were placed on each origin based on the percentage supplied in 1974. For example Lawrence, Kansas supplied 15.42 percent of the total volume supplied by the eight origins to the study area in 1974. Applying this 15.42 percent against projected 1980 demands, Lawrence's production capacity is constrained to 4610 tons of a total 29,841 tons demanded. The mode selection option to the trans-

Table 25. Destination, Origin and Mode Shifts Resulting From Rail Costs Being Reduced 20 and 40 Percent. (Tables 18, 20 and 22 Compared).

Destination	Original Origin	Original Mode 1	Origin 20% Reduction	Mode 20% Reduction	Origin 40% Reduction	Mode 40% Reduction
1	22	99	26	98	26	98
1	30	99	31	99	32	98
1	31	99	33	99		
2	31	99	32	99	31	98
2	32	99	34	98	32	98
3	33	99	33	99	33	99
4	30	99	30	99	30	99
5	31	99	31	99	32	98
5	34	99	34	98	34	98
6	31	99	31	99	31	99
7	32	99	32	99	32	99
7	33	99			33	99
8	33	99	33	99	33	99
9	22	99	22	99	22	99
9	26	98	26	98	26	98
9			30	99	30	99
10	32	99	32	99	32	99
11	34	99	34	99	34	99

1. 98 - Rail Service

   99 - Truck Service

portation linear programming model was also applied. Numbers were assigned each mode, 98 for rail transport and 99 for truck transport.

Presented in Table 26 is the optimum distribution system using combinations of rail and truck services. Evaluation of this table indicates that railroad (98) carried 32.2 percent (9,609 tons) of the tonnage and received 69.98 percent ($189,665.92) of the revenue. Truck service (99) carried 67.8 percent of the volume (20,232 tons) and received 30.02 percent of the revenue ($81,364.86). Total transport cost to the study area equalled $271,030.78. A comparison between Tables 5 and 26 indicates 33 percent rail utilization in 1974 for the transport of liquid fertilizer to the study area while in Analysis No. 1 rail utilization was 32.2 percent. Truck utilization in 1974 was 67 percent based on all sample shipment data and 67.8 percent in Analysis No. 1. Presented in Table 27 is the liquid fertilizer distribution system developed from sample shipment data compared to the liquid fertilizer distribution developed through the use of the transportation linear programming model, Table 26.

Evaluation of the sample shipment data for 1974 indicates that 65 percent of liquid fertilizer was delivered to the study area by truck and 35 percent by rail. This compares with 67.8 percent by truck and 32.2 percent by rail in the linear programming model, Table 26.

Total cost of transporting liquid fertilizer totally by rail was 8.23 percent higher than a combination of modes and transporting by truck was 2.03 percent higher. Again, indicating that intermodal combinations of rail and truck services provide the most economical distribution system to the study area. Like the anhydrous ammonia computer runs, these particular liquid fertilizer runs are not presented in table form.

Table 26. Liquid Fertilizer Distribution System Assuming Production Capacities Based on Percentage Supplied in 1974 From Eight Major Supply Origins and Combination of Rail and Truck Services With Fully Distributed Rail Costs.

Origin	Destination	Quantity (Tons)	Unit Cost ($/Ton)	Total Cost (Dollars)	Mode 1
22	1	2984	2.52	7519.68	99
23	1	1380	2.04	2815.20	99
25	1	1577	5.88	9272.76	99
20	2	388	19.22	6496.36	99
20	3	211	19.58	4131.38	98
21	3	3014	2.89	8710.46	99
26	4	3610	4.22	15234.20	99
23	5	285	2.65	755.25	99
26	5	619	5.68	3515.92	99
20	6	927	18.41	17066.07	98
24	6	1233	27.35	33722.55	98
26	6	381	5.03	1916.43	99
27	6	1652	12.10	19989.20	98
20	7	152	21.06	3201.12	98
27	7	950	14.75	14012.50	98
20	8	3055	20.35	62169.25	98
25	9	6376	4.96	31624.96	99
20	10	344	20.80	6947.20	98
24	11	757	28.97	21930.29	98
Total		29841		271,030.78	

1. 98 - Rail Service

   99 - Truck Service

Presented in Table 27 is the liquid fertilizer distribution system developed from sample shipment data using the same origins selected for the model, compared to the liquid fertilizer distribution system developed through the use of the transportation linear programming model, Table 26. The distribution system developed by computer model (Table 26) utilizes fewer origin/destination combinations to distribute liquid fertilizer than were reported in the dealer survey. Dealers surveyed averaged 1.86 origins per dealer while the model averaged 1.73 origins for each destination. Again, this is to be expected since sample shipment data represents real world situations reflecting price and timely availability of fertilizer from various sources, whereas, the model sets up a single criteria (transport cost) as the controlling basis for determining the distribution pattern for fertilizer.

ANALYSIS NO. 2

In this analysis the limitations are the same as presented in Analysis No. 1 with the exception of rail costs which are reduced 20 percent to reflect approximately one-half of allocated fixed costs in determining costs. The mode selection option was also used in this analysis. The purpose of this analysis was to determine what effect reducing rail costs to a point where approximately one-half of the fixed costs are recovered would have on competition between rail and truck services.

A comparison between Tables 26 and 28 indicates a shift in distribution to increased use of rail service. Rail shipments increased from 9609 tons in Analysis No. 1 to 21864 tons in Analysis No. 2 (127 percent increase). Truck shipments decreased from 20232 tons in Analysis No. 1 to 7977 tons in Analysis No. 2 (154 percent decrease).

Table 27. Sample Liquid Fertilizer Shipment Data Compared to the Liquid Fertilizer Distribution System Presented in Table 26.

Sample Shipment Data			The Model		
Origin	Destination	Mode[1]	Origin	Destination	Mode[1]
22	1	99	22	1	99
23	1	99	23	1	99
24	1	99	25	1	99
25	1	98			
No Record	2		20	2	98
No Record	3		20	3	98
			21	3	99
20	4	99	26	4	99
26	4	98			
26	5	99	23	5	99
			26	5	99
26	6	99	20	6	98
27	6	99	24	6	99
27	6	98	26	6	98
			27	6	98
No Record	7		20	7	98
			27	7	98
26	8	99	20	8	98
21	9	99	25	9	99
No Record	10		20	10	98
26	11	99	24	11	98

1. 98 - Rail Service

   99 - Truck Service

Table 28. Liquid Fertilizer Distribution System Assuming Production Capacities Based on Percentage Supplied in 1974 From Eight Major Supply Origins and Combinations of Rail and Truck Services With Rail Costs Reduced 20 Percent.

Origin	Destination	Quantity (Tons)	Unit Cost ($/Ton)	Total Cost (Dollars)	Mode [1]
23	1	1665	2.04	3396.60	99
25	1	4276	5.55	23731.80	98
24	2	73	22.53	1644.69	98
27	2	265	10.33	2737.45	98
21	3	3014	2.89	8710.46	99
25	3	211	5.78	1219.58	98
24	4	1293	21.29	27572.97	98
26	4	314	4.22	1325.08	99
27	4	2003	9.09	18207.27	98
26	5	904	5.11	4619.44	98
20	6	3235	14.73	47651.55	98
24	6	624	21.88	13653.12	98
27	6	334	9.68	3233.12	98
20	7	697	16.85	11744.45	98
25	7	411	7.37	3029.07	98
25	8	3055	6.79	20743.45	98
22	9	2984	1.60	4774.40	99
26	9	3392	4.33	14687.36	98
20	10	334	16.64	5557.76	98
20	11	757	16.03	12134.71	98
Total		29841		230,329.33	

1. 98 - Rail Service

   99 - Truck Service

Revenue shifts also occurred as a result of reducing rail transport costs. Rail revenue in Analysis No. 1 totalled $189,666 while in Analysis No. 2 rail revenue increased to $212,123 (12 percent increase). Truck revenue decreased from $81,364 (Analysis No. 1) to $18,207 (Analysis No. 2), a 347 percent decrease.

Presented in Table 29 is a comparison showing origin/destination and mode utilization shifts as a result of reducing rail costs by 20 percent.

ANALYSIS NO. 3

In this analysis the limitations are the same as presented in Analysis No. 1 with the exception of rail costs which are reduced 40 percent to reflect rail rates recovering only rail out-of-pocket costs. The mode selection option was also used in this analysis.

The purpose of this analysis was to determine what effect reducing rail costs to a point where only out-of-pocket costs are recovered would have on competition between rail and truck services in movement of liquid fertilizers.

A comparison between Tables 28 and 30 indicates a further shift towards increased rail service. Rail shipments increased from 21,864 tons in Analysis No. 2 to 22,107 tons in Analysis No. 3 (1.11 percent increase). Comparing rail shipments in Analysis No. 1 to those in Analysis No. 3 indicates a 130 percent increase in rail service when rail costs are reduced by 40 percent (9,609 tons in Analysis No. 1 to 22,107 tons in Analysis No. 3). Truck shipments decreased to 7734 tons (3.14 percent below Analysis No. 2 and 161.6 percent below Analysis No. 1).

Table 29. Shifts in Destination, Origin and Mode Resulting From Rail Costs Being Reduced 20 Percent. (Table 26 Compared to Table 28).

Destination	Original Origin	Original Mode	Origin Changes	Mode Changes [1]
1	22	99	23	99
1	23	99	25	98
1	25	99		
2	20	98	24	98
2			27	98
3	20	98	21	99
3	21	99	25	98
4	26	99	24	98
4			26	99
4			27	98
5	23	99	26	98
5	26	99		
6	20	98	20	98
6	24	98	24	98
6	26	99	27	98
6	27	98		
7	20	98	20	98
7	27	98	25	98
8	20	98	25	98
9	25	99	22	99
9			26	98
10	20	98	20	98
11	24	98	20	98

1. 98 - Rail Service

   99 - Truck Service

Table 30. Liquid Fertilizer Distribution System Assuming Production Capacities Based on Percentage Supplied in 1974 From Eight Major Supply Origins and Combinations of Rail and Truck Services with Rail Costs Reduced 40 Percent.

Origin	Destination	Quantity (Tons)	Unit Cost ($/Ton)	Total Cost (Dollars)	Mode [1]
20	1	697	11.27	7855.19	98
23	1	1665	2.04	3396.60	99
25	1	3579	4.16	14888.64	98
20	2	24	11.53	276.72	98
26	2	314	4.01	1259.14	98
21	3	3014	2.89	8710.46	99
25	3	211	4.34	915.74	98
20	4	3610	10.60	38266.00	98
26	5	904	4.01	3625.04	98
20	6	692	11.05	7646.60	98
24	6	1233	16.41	20233.53	98
27	6	2268	7.26	16465.68	98
25	7	1108	5.53	6127.24	98
25	8	3055	5.09	15549.95	98
22	9	2984	1.60	4774.40	99
27	10	334	8.69	2902.46	98
24	11	757	17.38	13156.66	98
Total		29841		160,050.05	

1. 98 - Rail Service

   99 - Truck Service

Presented in Table 31 are the shifts in origin and mode utilization resulting from a 40 percent reduction in rail costs compared with a 20 percent reduction in rail costs. Presented in Table 32 are the shifts in origin and mode utilization resulting from both a 20 and 40 percent reduction in rail costs compared with the original model in Analysis No. 1. A cost reduction of $70,279 over Analysis No. 2 and $110,980 over Analysis No. 1 could also be realized by the study area assuming the railroads are willing to operate on less than fully-distributed costs which as pointed out in the anhydrous ammonia analysis, is a common practice by railroads given specific hauls and particular competitive situations.

Shifts in revenue also occurred as a result of reducing rail cost by 40 percent. Rail revenue decreased from $212,123 in Analysis No. 2 to $143,169 in Analysis No. 3 (48 percent decrease) and from $189,666 in Analysis No. 1 (32 percent decrease). Truck revenue also decreased. Truck revenue in Analysis No. 2 equalled $18,206 while in Analysis No. 3 it decreased to $16,881 (8 percent decrease) and from $81,364 in Analysis No. 1 (382 percent decrease).

DRY BULK NITROGEN ANALYSES

Five origins or transhipment points directly supplying 40 percent of the demand in 1974 were selected for these analyses: Donaldsonville, Louisiana; Houston, Texas; Joplin, Missouri; and Kansas City and Lawrence, Kansas. Since dry bulk nitrogen is an easily stored product, there were many indirect shipments into the study area from origins which were neither a plant location nor intermodal transhipment points. This is the reason for the smaller percentage supplied directly to the study area dealers by the dry bulk nitrogen manufacturing points as indicated in Appendix B.

Table 31. Shifts in Destination, Origin and Mode Resulting From Rail Costs Being Reduced From 20 to 40 Percent. (Table 28 Compared to Table 30).

Destination	Original Origin	Original Mode	Origin Changes	Mode 1 Changes
1	23	99	20	98
1	25	98	23	99
1			25	98
2	24	98	20	98
2	27	98	26	98
3	21	99	21	99
3	25	98	25	98
4	24	98	20	98
4	26	99		
4	27	98		
5	26	98	26	98
6	20	98	20	98
6	24	98	24	98
6	27	98	27	98
7	20	98	25	98
7	25	98		
8	25	98	25	98
9	22	99	22	99
9	26	98		
10	20	98	27	98
11	20	98	24	98

1. 98 - Rail Service

   99 - Truck Service

Table 32. Shifts in Destination, Origin and Mode Resulting From Rail Costs Being Reduced 20 and 40 Percent (Tables 26, 28 and 30 Compared)

Destination	Original Origin	Original Mode 1	Origin 20% Reduction	Mode[1] 20% Reduction	Origin 40% Reduction	Mode[1] 40% Reduction
1	22	99	23	99	20	98
1	23	99	25	98	23	99
1	25	99			25	98
2	20	98	24	98	20	98
2			27	98	26	98
3	20	98	21	99	21	99
3	21	99	25	98	25	98
4	26	99	24	98	20	98
4			26	99		
4			27	98		
5	23	99	26	98	26	98
5	26	99				
6	20	98	20	98	20	98
6	24	98	24	98	24	98
6	26	99	27	98	27	98
6	27	98				
7	20	98	20	98	25	98
7	27	98	25	98		
8	20	98	25	98	25	98
9	25	99	22	99	22	99
9			26	98		
10	20	98	20	98	27	98
11	24	98	20	98	24	98

1. 98 - Rail Service

   99 - Truck Service

ANALYSIS NO. 1

In this analysis limitations were placed on each origin based on the percentage supplied in 1974. For example, Houston, Texas supplied 13.59 percent of the total volume supplied by the five origins to the study area in 1974. Applying this 13.59 percent against 1980 demands, Houston's production capacity is constrained to 6,280 tons out of a total of 46,210 tons demanded. The mode selection option to the transportation linear programming model was also applied. Numbers were assigned each mode, 98 for rail transport and 99 for truck transport.

Presented in Table 33 is the optimum distribution system using intermodal combinations of rail and truck services. A comparison of Tables 5 and 33 indicates that 75 percent of dry bulk nitrogen was transported by rail in 1974 while in Analysis No. 1 rail utilization was 42.14 percent. Trucks transported 25 percent based on sample shipment data and 57.86 percent in Analysis No. 1.

Further analysis (Table 33) indicates that rail service received 56.26 percent of the revenue in the transportation linear programming model while truck service received 42.74 percent. Total transport cost to the study area were $497,003.

Presented in Table 34 is the dry bulk nitrogen distribution system developed from sample shipment data as compared to the distribution system developed in Analysis No. 1, Table 33. A comparison of these two distribution systems indicates truck utilization, based on the sample shipment using only the origins selected for this study, was 43 percent compared to 57.86 percent in Analysis No. 1. Rail utilization based on the aforementioned origins, was 57 percent in the sample data and 42.14 percent in Analysis No. 1.

Table 33. Dry Bulk Nitrogen Distribution System Assuming Production Capacities Based on Percentage Supplied in 1974 From Five Major Supply Origins and Combinations of Rail and Truck Services with Fully-Distributed Rail Costs.

Origin	Destination	Quantity (Tons)	Unit Cost ($/Ton)	Total Cost (Dollars)	Mode [1]
40	1	5088	23.62	120178.56	98
43	1	2670	10.17	27153.90	98
26	2	3162	5.85	18497.70	99
42	2	2736	19.35	52941.60	98
43	3	1392	10.79	15019.68	98
26	4	7023	4.05	28443.15	99
26	5	6573	5.46	35888.58	99
26	6	3124	4.84	15120.16	99
43	7	1747	11.95	20876.65	98
43	8	1167	11.39	13292.13	98
26	9	386	5.17	1995.62	99
40	9	161	23.12	3722.32	98
43	9	968	9.67	9360.56	98
44	9	6469	14.67	94900.23	99
43	10	161	11.75	1891.75	98
43	11	3383	11.15	37720.45	98
Total		46210		497003.04	

1. 98 - Rail Service

99 - Truck Service

Table 34. Sample Dry Bulk Nitrogen Fertilizer Shipment Data Compared to the Dry Bulk Fertilizer Distribution System Presented in Table 31.

Sample Shipment Data			The Model	
Destination	Origin	Mode	Origin	Mode
1	26	99	40	98
1	40	98	43	98
2			26	99
2	No Record	No Record	42	98
3	26	99	43	98
3	40	98		
3	26	98		
4	43	99	26	99
4	44	99		
4	26	99		
4	42	98		
4	43	98		
4	44	98		
4	26	98		
5	43	99	26	99
5	44	99		
5	26	99		
5	43	98		
6	40	98	26	99
7	44	98	43	98
8	26	98	43	98
9	No Record	No Record	26	99
9			40	98
9			43	98
9			44	98
10	26	99	43	98
10	44	99		
11	44	98	43	98

1. 98 - Rail Service

   99 - Truck Service

Another comparison was made between the results of Analysis No. 1, Table 33, and two other computer runs where the limitations were the same as in Analysis No. 1, with the exception that truck and rail services which were each withdrawn into the model one at a time. In the model where only truck service was allowed to enter, transport costs for the study area were $607,593. This is $110,590 (22 percent) higher than the distribution costs in Analysis No. 1. In the model where only rail service was allowed to enter, distribution costs to the study area were $553,889 (11 percent) higher than the distribution costs in Analysis No. 1. Again, the two models showing rail services and truck service entered into the model separately are not presented in table form.

ANALYSIS NO. 2

In this analysis the limitations are the same as presented in Analysis No. 1 with the exception of rail costs which are reduced 20 percent to reflect approximately one-half of allocated costs in determination of fully-distributed costs. The mode selection option was also used in this analysis.

The purpose of this analysis was to determine what the effect would be on volume by each mode of reducing rail costs to a point where approximately one-half of the fixed costs are recovered. A comparison between Tables 33 and 35 indicates rail shipments increased from 42.14 percent in Analysis No. 1 to 84.8 percent in Analysis No. 2. Rail revenue also increased from $284,607 in Analysis No. 1 to $422,650 in Analysis No. 2. Truck shipment decreased from 57.86 percent in Analysis No. 1 to 15.2 percent in Analysis No. 2. Truck revenue decreased by $184,252, from $212,394 in Analysis No. 1 to $28,443 in Analysis No. 2.

Table 35. Dry Bulk Nitrogen Distribution System Assuming Production Capacities Based on Percentage Supplied in 1974 from Five Major Supply Origins and Combinations of Rail and Truck Services with Rail Costs Reduced 20 Percent.

Origin	Destination	Quantity (Tons)	Unit Cost ($/Ton)	Total Cost (Dollars)	Mode [1]
43	1	4413	8.14	35921.82	98
44	1	3345	13.91	46528.95	98
26	2	649	5.40	3504.60	98
40	2	5249	19.17	100623.33	98
43	3	1392	8.63	12012.96	98
26	4	7023	4.05	28443.15	99
42	5	6280	15.45	97026.00	98
43	5	293	8.39	2458.27	98
44	6	3124	13.38	41799.12	98
43	7	1747	9.56	16701.32	98
26	8	1068	6.10	6514.80	98
43	8	99	9.11	901.89	98
26	9	7996	4.72	37741.12	98
26	10	161	6.38	1027.18	98
26	11	3371	5.90	19888.90	98
Total		46210		451,093.41	

1. 98 - Rail Service

   99 - Truck Service

Total transport cost to the study area decreased to $451,093 in Analysis No. 2 from $497,003 in Analysis No. 1.

Presented in Table 36 are the shifts in origin and mode utilization resulting from a 20 percent reduction in rail costs.

ANALYSIS NO. 3

In this analysis the limitations are the same as presented in Analysis No. 1 with the exception of rail costs which are reduced 40 percent to reflect only out-of-pocket costs being recovered by the railroads.

The purpose of this analysis was to determine what effect reducing rail costs to a point where only out-of-pocket costs are recovered would have on competition between rail and truck services, Table 37. A comparison between Tables 35 and 37 indicates a complete shift to rail service. Rail revenue, however, decreased from $422,650 in Analysis No. 2 to $353,528 in Analysis No. 3. Total transport costs to the study area also decreased from $451,093 in Analysis No. 2 and $497,003 in Analysis No. 1 to $353,528 in Analysis No. 3, a $69,122 and $143,475 decrease, respectively.

Presented in Table 38 are the shifts in origin and mode utilization resulting from a 40 percent reduction in rail costs compared with a 20 percent reduction in rail costs. Presented in Table 39 are the shifts in origin and mode utilization resulting from both a 20 and 40 percent reduction in rail costs compared with the original mode in Analysis No. 1.

Table 36. Shifts in Destination, Origin and Mode Resulting From Rail Costs Being Reduced 20 Percent (Table 33 Compared to Table 35)

Destination	Original Origin	Original Mode[1]	Origin Change	Mode Change[1]
1	40	98	43	98
1	43	98	44	98
2	26	99	26	98
2	42	98	40	98
3	26	99	43	98
4	26	99	26	99
5	26	99	42	98
6	26	99	44	98
7	43	98	43	98
8	43	98	26	98
8			43	98
9	40	98	26	98
9	43	98		
9	44	99		
10	43	98	26	98
11	43	98	26	98

1. 98 - Rail Service

   99 - Truck Service

Table 37. Dry Bulk Nitrogen Distribution System Assuming Production Capacities Based on Percentage Supplied in 1974 from Five Major Supply Origins and Combinations of Rail and Truck Services with Rail Costs Reduced 40 Percent.

Origin	Destination	Quantity (Tons)	Unit Cost ($/Ton)	Total Cost (Dollars)	Mode [1]
40	1	1743	14.17	24698.31	98
43	1	2670	6.10	16287.00	98
44	1	3345	12.48	41745.60	98
26	2	5898	4.05	23886.90	98
43	3	1392	6.47	9006.24	98
26	4	89	3.32	295.48	98
40	4	3345	13.64	45625.80	98
43	4	3589	5.57	19990.73	98
42	5	6280	11.59	72785.20	98
43	5	293	6.29	1842.97	98
44	6	3124	12.09	37769.16	98
26	7	1747	4.91	8577.77	98
26	8	1167	4.58	5344.86	98
26	9	7996	3.54	28305.84	98
40	10	161	15.11	2432.71	98
26	11	3371	4.43	14933.53	98
Total		46210		353,528.10	

1. 98 - Rail Service

   99 - Truck Service

Table 38. Shifts in Distribution, Origin and Mode Resulting From Rail Costs Being Reduced From 20 to 40 Percent. (Table 35 Compared to Table 37).

Destination	Original Origin	Original Mode 1	Origin Change	Mode 1 Change
1	43	98	40	98
1	44	98	43	98
1			44	98
2	26	98	26	98
2	40	98		
3	43	98	43	98
4	26	99	26	98
4			40	98
4			43	98
5	42	98	42	98
5	42	98	43	98
6	44	98	44	98
7	43	98	26	98
8	26	98	26	98
8	43	98		
9	26	98	26	98
10	26	98	40	98
11	26	98	26	98

1. 98 - Rail Service

   99 - Truck Service

Table 39. Shifts in Destination, Origin and Mode Resulting From Rail Costs Being Reduced 20 and 40 Percent (Tables 33, 35 and 37 Compared).

Destination	Original Origin	Original Mode 1	Origin 20% Reduction	Mode 1 20% Reduction	Origin 40% Reduction	Mode 1 40% Reduction
1	40	98	43	98	40	98
1	43	98	44	98	43	98
1					44	98
2	26	99	26	98	26	98
2	42	98	40	98		
3	26	99	43	98	43	98
4	26	99	26	99	26	98
4					40	98
4					43	98
5	26	99	42	98	42	98
5					43	98
6	26	99	44	98	44	98
7	43	98	43	98	26	98
8	43	98	26	98	26	98
8			43	98		
9	40	98	26	98	26	98
9	43	98				
9	44	99				
10	43	98	26	98	40	98
11	43	98	26	98	26	98

1. 98 - Rail Service

99 - Truck Service

DRY BULK PHOSPHATE ANALYSES

Since there were only two major suppliers of dry bulk phosphate fertilizer to the study area (Greenbay and Tampa, Florida) the transportation linear programming model was not applied to these analyses.

ANALYSIS NO. 1

Since it has already been established in the dry bulk nitrogen analysis that rail service from Kansas City, Kansas to any destination point is more economical than truck service, the purpose of this analysis was to compare rail transport costs from Greenbay and Tampa, Florida to Kansas City, Kansas.

It was determined that Greenbay, Florida is the more economical origin.

ANALYSIS NO. 2

In this analysis rail transport costs from Greenbay, Florida to Kansas City, Kansas were compared to barge transport costs from Tampa, Florida to Kansas City, Kansas. It was determined that barging dry bulk phosphate from Tampa, Florida to Kansas City, Kansas, rather than using rail service to each destination point is more economical than rail service directly from Greenbay, Florida to each destination point by $7.49 per ton. This savings is based on estimates of costs from available data and does not include service differentials such as speed of transport and ease of scheduling movement.

SUMMARY OF DISTRIBUTION ANALYSES

It was determined in the anhydrous ammonia, liquid fertilizer and dry bulk nitrogen analyses that intermodal combinations of rail and truck

services provide the most economical means of fertilizer distribution to the study area. It was also determined that the railroad and trucking industries are in close cost competition as indicated by the shift to rail service as rail costs are reduced 20 percent to reflect approximately one-half of the fixed costs being recovered and 40 percent to reflect only out-of-pocket costs being recovered.

In the anhydrous ammonia analyses, due to proximity of origins to destinations truck service is the most utilized mode of transport assuming railroads operate at fully-distributed cost levels. In Analysis No. 1 truck service accounted for 92.94 percent of the volume transported (64,322 tons) while rail service transported 7.06 percent of the volume (4,886 tons). Truck service also received the greatest portion of the revenue 90.73 percent ($284,979) while rail service received 9.27 percent ($26,433).

In Analysis No. 2 where rail costs were reduced 20 percent, shifts occurred in mode utilization. Rail volume increased to 8286 tons (41.03 percent) while truck volume decreased to 60,922 tons (5.58 percent). Rail revenue also increased from $26,433 in Analysis No. 1 to $42,925 in Analysis No. 2 (38.42 percent decrease). Truck revenue decreased in Analysis No. 2 to $233,901 (10.54 percent). Total transport cost to the study area decreased from $284,979 in Analysis No. 1 to $276,826 in Analysis No. 2 (2.94 percent).

In Analysis No. 3 reducing rail cost by 40 percent caused a further shift towards rail service utilization. Rail service volume increased to 27,056 tons (69.37 percent over Analysis No. 2 and 81.94 percent over Analysis No. 1) while truck service volume decreased to 42,152 tons (44.53 percent below Analysis No. 2 and 52.59 percent below Analysis No. 1). Further

revenue shifts also occurred. Rail revenue increased to $122,849 (65.06 percent above Analysis No. 2 and 78.48 percent above Analysis No. 1) while truck revenue decreased to $123,046 (90.09 percent below Analysis No. 2 and 110.12 percent below Analysis No. 1). Total transport cost also decreased from $276,826 in Analysis No. 2 to $245,895 in Analysis No. 3 (11.17 percent).

In the liquid fertilizer analyses it was determined in Analysis No. 1 that truck service is the most utilized mode of transport. Truck service received 20,232 tons (67.8 percent) of the volume while rail service received 9,609 tons (32.2 percent) of the volume. The opposite occurred for revenue distribution. Rail service received $189,665 (69.98 percent) of the revenue while truck service received $81,364 (30.02 percent). This is a result of the proximity of five of the liquid fertilizer origins to the study area. These origins supplied 74.21 percent of the volume through the use of truck service, but generated short haul low revenue producing shipments. Total cost to the study area was $271,030.

In Analysis No. 2 the reduction of rail cost by 20 percent caused truck service to decrease to 7,977 tons (153.64 percent) while rail volume increased to 21,864 tons (127.54 percent). Truck revenue also decreased from $81,364 in Analysis No. 1 to $18,206 in Analysis No. 2 (346.91 percent decrease). Rail revenue increased from $189,665 in Analysis No. 1 to $212,122 in Analysis No. 2 (11.84 percent increase). Total transport cost to the study area decreased to $230,329 (17.67 percent).

In Analysis No. 3 reducing rail costs by 40 percent caused a further shift towards rail service. Rail volume increased to 22,107 tons, 243 tons (1.11 percent) above Analysis No. 2 and 12,498 tons above Analysis

No. 1 (130 percent). Rail revenue decreased, however, to $143,168; $68,954 below Analysis No. 1 (48.16 percent) and $46,497 below Analysis No. 1 (32.48 percent). Truck volume decreased from 7,977 tons in Analysis No. 2 and 20,232 tons in Analysis No. 1 to 7,734 tons in Analysis No. 3 (3.14 and 161.6 percent decrease, respectively).

Truck revenue also decreased from $81,364 in Analysis No. 1 to 18,206 in Analysis No. 2 to $16,881 in Analysis No. 3. Total transport cost to the study area decreased to $160,050; $70,279 below Analysis No. 2 and $110,980 below Analysis No. 1 (69.34 and 43.91 percent decreases, respectively).

In the dry bulk nitrogen fertilizer analyses, it was determined in Analysis No. 1 that rail service is the most utilized transport mode. Rail service received 19,473 tons (42.14 percent) of the volume and $284,607 (57.26 percent) of the revenue. Truck service received 26,737 tons (57.86 percent) of the volume and $212,395 (42.74 percent) of the revenue. Total cost to the study area was $497,003.

In Analysis No. 2 the reduction of rail costs by 20 percent caused rail utilization to increase to 39,187 tons (101.24 percent increase above Analysis No. 1). Rail revenue increased from $284,607 in Analysis No. 1 to $422,650 in Analysis No. 2 (48.5 percent). Truck utilization decreased from 26,737 tons in Analysis No. 1 to 7,023 tons in Analysis No. 2 (280.71 percent decrease).

Truck revenue also decreased from Analysis No. 1 by 646.74 percent ($183,952). Total transport costs to the study area decreased to $451,093.

In Analysis No. 3 reducing rail costs by 40 percent caused a complete shift to rail service. However, rail revenue decreased from $422,650 in Analysis No. 2 to $353,528 in Analysis No. 3 (19.55 percent decrease).

Total transport cost to the study area also decreased from $497,003 in Analysis No. 1 to $451,093 in Analysis No. 2 to $353,528 in Analysis No. 3. (27.6 and 40.50 percent decreases), respectively.

In the dry bulk phosphate analyses, it was determined in Analysis No. 1 that rail service from Greenbay, Florida provides the most economical direct rail transport to the study area. In Analysis No. 2 it was determined that a barge-rail combination from Tampa, Florida via Kansas City, Kansas results in the most economical way to move dry bulk phosphate to the study area by $7.49 per ton.

CHAPTER VIII

Summary and Conclusions

This chapter is a summary of the results of the distribution analyses for anhydrous ammonia, liquid fertilizer, dry bulk nitrogen and dry bulk phosphate. In addition, conclusions have been drawn, limitations of the present study are presented and the need for further research is outlined.

Summary

An effective transportation system is essential before the rural sector can contribute fully to the national economy. At times rural transportation demands have become so great that the existing system has not been sufficient. A recent example of this was an equipment shortage which started in the fall of 1972 and lasted into 1974.

The transportation industry, like almost any American industry, is in a state of change. Many railroads have experienced large financial losses on light density rail line operations resulting in rail line abandonment, trucking companies have experienced increased operating costs resulting from higher energy costs, and pipeline companies have had to limit expansion because of increased material and installation costs.

The economic connotations related to current changes taking place in the transportation industry are of prime concern to many rural American communities. Rail line abandonment, for example, can have a profound

impact on a local grain elevator which depends on rail service to move large volumes of grain and loss of this service could mean increased transportation costs resulting in a loss of competitive position in the market.

Rail line abandonment could also affect the area producer. For example, if local elevators are forced to close, the distance producers must haul grain will increase and distance traveled to acquire farming inputs will increase.

Local communities could also be affected by rail line abandonment. Local property tax revenues may be reduced and railroad employment levels may be cut, resulting in a loss of the economic activity generated by these employees.

With these problems in mind, the purpose of this study is to determine the manner in which fertilizer delivery in the study area involves various elements of the transportation system and how varying levels of railroad cost affect the cost and pattern of fertilizer delivery to the study area.

Specific objectives of this study are: (1) to determine the present interregional transportation inputs into wholesale distribution of fertilizer in the North Central Crop Reporting District of Kansas; (2) to relate estimates of fertilizer use in 1980 to estimates of transportation requirements by mode with cost minimizing transport configurations; (3) to relate present interregional transportation inputs into wholesale distribution of fertilizer in the North Central Crop Reporting District of Kansas to estimated transportation requirements by mode with cost minimizing transport configurations and (4) to determine changes in the optimum inputs for the District for 1980 assuming varying levels of railroad transport cost conditions.

A network model was used to determine the distances between all origins and destinations. In this study, a total of 22 origins (production points) and 11 destination (demand points) were connected by distance links of available railroads and highways in order to determine routes. The cost of delivering fertilizer by rail was developed by using Rail Carload Cost Scales for 1972 updated 18 percent to reflect inflation factors. Truck costs were supplied by industry sources. Transhipment costs for pipeline movement of anhydrous ammonia were supplied by Mid-American Pipeline Company, Inc. (MAPCO). Dry bulk fertilizer barge transhipment costs were developed in a previous study done for the Army Corps of Engineers. These costs were then applied to the distance matrixes derived from the network analysis. This results in a cost matrix for both rail and truck services for all origins and destinations.

The transportation linear programming analysis was employed to determine the least-cost solution for three of the four product groupings under three different analyses, assuming varying levels of cost and supply conditions. The transportation linear programming model was not employed to calculate dry bulk phosphate fertilizer distributions. The demand for fertilizer is based on projected 1980 demands. Demand figures were previously calculated in a study done for the Army Corps of Engineers.

From the interview questionnaire developed for this study, it was determined that dealer ownership is evenly distributed between the three categories: privately owned dealerships; cooperatives; and corporately-owned dealerships. Also determined was the fact that 73 percent of the fertilizer distributed in the study area is distributed through or in conjuction with a grain elevator operation. It was also determined that

the majority of fertilizer is shipped during the months of March, April and May with the heaviest flow occurring in April.

It was also determined that anhydrous ammonia is primarily transported to the study area by truck, with a five-year average (1970 thru 1974) of 94 percent truck movement and 6 percent rail movement. Truck shipment also dominates liquid fertilizer movements with a five-year average (1970 thru 1974) of 83 percent truck movement and 17 percent rail movement. A five-year average (1970 thru 1974) of dry bulk fertilizer movement indicates that rail service is the primary mode, with 75 percent by rail and 25 percent by truck.

Also determined from the survey were the major fertilizer supply points for anhydrous ammonia, liquid fertilizer, dry bulk nitrogen and dry bulk phosphate. For anhydrous ammonia points were Clay Center, Conway, Dodge City, Lawrence and Wichita, Kansas and Hastings, Nebraska. The origin or transhipment points combined supplied 88 percent of the anhydrous ammonia delivered to dealers in the study area in 1974.

Major liquid fertilizer supply points were Aurora, Davenport and Beatrice, Nebraska; Lawrence, Kansas; Louisiana, Missouri; Geismare, Louisiana; and Armorel, Arkansas. These origins supplied 77 percent of total deliveries in 1974.

Major dry bulk fertilizer supply and transhipment points were Joplin, Missouri; Kansas City, Kansas; Donaldsonville, Louisiana; Houston, Texas; and Tampa and Greenbay, Florida.

From the analyses portion of this study, it was determined that intermodal combinations of rail and truck services provide the most economical means of fertilizer distributions to the study area. It was also

determined that the railroad and trucking industries are in close cost competition as indicated by the shift to rail service as rail costs were reduced.

In the anhydrous ammonia analyses, due to the proximity of origins to destinations, truck service is the most utilized mode of transport assuming railroads operate at fully-distributed cost levels. In Analysis No. 1, truck service accounted for 93 percent of the volume and received 91 percent of the revenue. Rail service in this analysis received 7 percent of the volume and 9 percent of the revenue.

In anhydrous ammonia Analysis No. 2 reducing rail costs 20 percent caused truck volume to decrease to 88 percent and truck revenue to decrease to 84 percent, while rail volume increased to 12 percent and revenue to 16 percent.

In anhydrous ammonia Analysis No. 3, reducing rail costs by 40 percent caused truck volume to decrease to 61 percent and revenue to 50 percent. Rail volume increased to 39 percent and revenue to 50 percent.

In the liquid fertilizer analyses, truck service also proved to be the most utilized transport mode assuming fully-distributed rail costs. In Analysis No. 1, truck service received 68 percent of the volume, but only 30 percent of the revenue. This was a result of the proximity of five of the liquid fertilizer origins to the study area. These origins supplied 68 percent of the volume through the use of truck service, but generated short haul, low revenue producing shipments. Rail service received 32 percent of the volume, but 70 percent of the revenue.

In Analysis No. 2, reducing rail cost 20 percent decreased truck service to 27 percent of the volume transported while rail volume increased

to 73 percent. Truck revenue also decreased to 8 percent of the total revenue generated while rail revenue increased to 92 percent.

In Analysis No. 3, reducing rail costs by 40 percent caused truck volume to decrease to 26 percent and revenue to 11 percent. Rail volume increased to 74 percent and revenue to 89 percent.

In the dry bulk nitrogen analyses, truck service proved to be the most utilized mode of transport assuming fully-distributed rail costs. In Analysis No. 1, truck service received 58 percent of the volume and 43 percent of the revenue while rail service received 42 percent of the volume and 57 percent of the revenue.

In Analysis No. 2, reducing rail costs by 20 percent caused truck volume to decrease to 15 percent and revenue to 6 percent. Rail volume increased to 85 percent and revenue to 94 percent.

In Analysis No. 3, reducing rail costs by 40 percent caused a complete shift to rail service.

In the dry bulk phosphate analyses, it was determined that rail service from Greenbay, Florida provides the most economical direct rail transportation to the study area. It was also determined that a barge-rail combination from Tampa, Florida via Kansas City, Kansas results in the most economical way to move dry bulk phosphate to the study area from the origins selected for the purposes of this study.

Conclusions

It can be concluded from this study that an increased demand for fertilizer transportation in rural areas will exist in future years. From the constraints set forth in this study, it can also be concluded that rail service can become highly competitive when operating on less

than fully-distributed costs. In the anhydrous ammonia analyses, rail service volume could increase from 7 percent to 39 percent and increase revenue from 9 percent to 50 percent by reducing costs by 40 percent.

Rail service could also increase its liquid fertilizer transport volume by reducing costs. In Analysis No. 2, reducing rail costs 20 percent causes rail volume to increase from 32 percent to 73 percent and revenue to increase from 70 percent to 92 percent. A 40 percent cost reduction caused rail transport volume to increase to 74 percent and revenue to decrease to 89 percent.

It can also be concluded that reducing rail costs 40 percent for the transport of dry bulk nitrogen could result in a complete shift to rail service.

Limitations of this Study

In order to represent the actual situation as closely as possible, it is necessary to minimize the number and use of assumptions when developing a study of this type.

The transportation linear program is the first limitation in that the least-cost solution may suggest actions which are more closely aligned to a central planning group where there is one producer and one owner of a fertilizer dealership. The model sets up a monopolistic situation when in actuality, pure competition may exist.

The transportation linear programming model also assumes perfect knowledge of demand, supply and transport costs to the shipper. Distribution patterns based on ex-post analysis do not incorporate risks and uncertainties associated with decision making within a period of economic activity.

A second limitation of this study relates to estimates of costs used. Because of time and resource limitations, detailed analysis of costs of operation by various modes has not been possible. Costs developed for this study are average costs obtained in some cases from secondary sources and in other cases from a limited number of observations from industry sources. Since transportation costs represent industry or area averages in some cases, they may not be representative of specific hauls in the study area. Rail costs, for example, may tend to be under-estimated over short distances and over-estimated over longer distances.

In spite of limitations in refinement of specific carrier cost data, this study demonstrates the importance of maintaining shipper options among carriers in delivery of fertilizer to the study area. The study also demonstrated the general nature of mode cost advantages and disadvantages in movement of various types of fertilizer and the influence of relative cost characteristics on the competitive position of each mode in providing fertilizer transport service to the rural area represented in this study.

Need for Further Study

With pending fuel shortages that may shift the relative competitive positions of the several modes of transportation, more refinement is desirable in the analysis of competitive positions and relative costs of various modes of transportation in serving agricultural and rural communities. More study should be directed to that purpose. Transport requirements of a single commodity (in this case, fertilizer) must also be combined

with those of other commodities for a better understanding of total transportation needs of rural communities.

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APPENDIX A

THE QUESTIONNAIRE

Dealer's Name: ______________________________

Dealer's Location: ______________ ______________
County Town

Type of Ownership: Private Cooperative Company or Corporation

Type of Business: Fertilizer Only Farm Supply

Grain Elevator and Fertilizer

Other ______________________________

Type of Product: Anhydrous Ammonia Liquid Nitrogen Dry Bulk

Dealers Service Area (Radius In Miles): ______________

General Questions:

Have you changed suppliers (YES NO) and why? ______________

____

Have you changed modes of transport (YES NO) and why? ______________

____

Why do you think your transport rates have changed? ______________

____

What supply problems have you had over the past few years? ______________

____

Do you see your suppliers changing (YES NO) why? ______________

____

What mode of transport do you see yourself using over the next few years?

____

What trends do you see in fertilizer use over the next few years?

Product change? ____

Volume change? ____

Have you had any problems with timeliness of delivery (YES NO) why? __

____

BASIC DATA SHEET APPENDIX A, continued

Dealer's Name ______________________ Year ______ Product ______________

Supplier's Name	Location	Date	Amount	Mode	Rate	Carrier's Name

APPENDIX B

FERTILIZER ORIGIN CODE NUMBERS

Anhydrous Ammonia	Liquid Fertilizers
22 Beatrice, Neb.	20 Armorel, Ark.
30 Clay Center, Ks.	21 Aurora, Neb.
31 Conway, Ks.	22 Beatrice, Neb.
32 Dodge City, Ks.	23 Davenport, Neb.
33 Hastings, Neb.	24 Geismare, La.
26 Lawrence, Ks.	25 LaPlatte, Neb.
34 Wichita, Ks.	26 Lawrence, Ks.
	27 Louisiana, Mo.

Dry Bulk

40 Donaldsonville, La.

41 Greenbay, Fla.

42 Houston, Tex.

43 Joplin, Mo.

44 Kansas City, Ks.

26 Lawrence, Ks.

45 Tampa, Fla.

APPENDIX C

COUNTY SEAT DESTINATION CODE NUMBERS

CODE	COUNTY	COUNTY SEAT
1	Republic	Belleville
2	Mitchell	Beloit
3	Jewell	Mankato
4	Clay	Clay Center
5	Cloud	Concordia
6	Ottawa	Minneapolis
7	Phillips	Phillipsburg
8	Smith	Smith Center
9	Washington	Washington
10	Rooks	Stockton
11	Osborne	Osborne

APPENDIX D

ANHYDROUS AMMONIA FERTILIZER TRUCK

MILEAGE MATRIX

Dest. \ Orig.	22	26	30	31	32	33	34
1	74	185	62	115	213	117	164
2	122	179	56	108	165	113	157
3	106	207	84	136	193	85	185
4	81	124	1	111	220	168	160
5	92	167	44	97	196	127	146
6	126	148	49	63	184	158	112
7	168	261	138	187	166	105	239
8	138	231	108	158	196	75	209
9	47	158	35	145	245	149	194
10	189	284	161	164	143	128	231
11	156	257	134	131	176	102	198

APPENDIX D, continued

LIQUID FERTILIZER TRUCK

MILEAGE MATRIX

Dest. \ Orig.	20	21	22	23	24	25	26	27
1	656	117	74	60	960	173	185	503
2	649	113	122	108	954	221	179	497
3	677	85	106	92	982	205	207	525
4	599	168	81	121	899	180	124	442
5	638	127	92	78	942	191	167	485
6	604	158	126	112	923	225	148	466
7	731	147	168	154	1036	267	261	579
8	701	117	138	124	1006	237	231	549
9	633	149	47	92	933	146	158	476
10	754	168	189	175	1059	288	284	602
11	727	135	156	142	1032	255	257	575

APPENDIX D, continued

DRY BULK FERTILIZER TRUCK

MILEAGE MATRIX

Dest. \ Orig.	26	40	41	42	43	44	45
1	185	912	1567	773	345	225	1525
2	179	905	1561	766	339	219	1519
3	207	933	1589	794	367	247	1547
4	124	901	1506	769	284	164	1464
5	167	894	1549	755	327	207	1507
6	148	860	1554	721	299	188	1512
7	261	987	1643	848	421	301	1601
8	231	957	1613	818	391	271	1571
9	158	935	1540	803	318	198	1498
10	284	1010	1666	840	444	324	1624
11	257	983	1639	807	417	297	1597

APPENDIX E

ANHYDROUS AMMONIA FERTILIZER RAIL

MILEAGE MATRIX

Orig. / Dest.	22	26	30	31	32	33	34
1	78	160	No	191	333	190	228
2	131	178	Rail	112	254	383	158
3	111	193	Service	224	366	157	261
4	125	113	.	144	286	237	181
5	102	178	.	119	261	370	156
6	165	144	.	78	220	349	124
7	173	255	.	286	428	209	323
8	143	225	.	256	398	179	293
9	57	133	.	164	306	325	201
10	197	244	.	154	296	449	224
11	165	212	.	122	264	417	192

APPENDIX E, continued

LIQUID FERTILIZER RAIL

MILEAGE MATRIX

Dest. \ Orig.	20	21	22	23	24	25	26	27
1	673	212	78	60	1047	177	160	409
2	691	405	131	253	1065	230	178	427
3	706	179	111	93	1080	210	193	442
4	626	259	125	107	1000	224	113	362
5	691	392	102	240	1065	201	178	427
6	657	371	165	219	1031	264	144	393
7	768	241	173	155	1142	272	255	504
8	738	211	143	125	1112	242	225	474
9	646	347	57	195	1020	156	113	382
10	757	471	197	319	1131	296	244	493
11	725	439	165	287	1099	264	212	461

APPENDIX E, continued

DRY BULK FERTILIZER RAIL

MILEAGE MATRIX

Dest. \ Orig.	26	40	41	42	43	44	45
1	160	1079	1573	921	361	199	1613
2	178	1097	1591	851	379	217	1631
3	193	1112	1606	954	394	232	1646
4	113	1032	1526	874	314	152	1566
5	178	1097	1591	849	378	217	1631
6	144	1063	1557	817	345	183	1597
7	255	1174	1668	1016	456	294	1708
8	225	1144	1638	986	426	264	1678
9	133	1052	1546	894	334	172	1586
10	244	1163	1657	917	445	283	1697
11	212	1131	1625	885	413	251	1665

AN ANALYSIS OF FERTILIZER TRANSPORTATION REQUIREMENTS
IN THE NORTH CENTRAL CROP REPORTING DISTRICT

by

BILLY M. SPANGLER

B. S., Kansas State University, 1973

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

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MASTERS OF SCIENCE

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Manhattan, Kansas

1979

Specific objectives of this study are: (1) to determine the present interregional transportation inputs into wholesale distribution of fertilizer in the North Central Crop Reporting District of Kansas; (2) to relate estimates of fertilizer use in 1980 to estimates of transportation requirements by mode with cost minimizing transport configurations; (3) to relate present interregional transportation inputs into wholesale distribution of fertilizer in the North Central Crop Reporting District of Kansas to estimated transportation requirements by mode with cost minimizing transport configurations and (4) to determine changes in the optimum inputs for the District for 1980 assuming varying levels of railroad transport cost conditions.

Data were collected by interview questionnaires developed for this study from a representative sample of fertilizer dealers operating in the study area. Dealer characteristics, operation features, and shipment records were recorded for the purpose of identifying the present fertilizer distribution system. Based on the present distribution system, major suppliers were identified and used as fertilizer origin or transhipment points in this study. County seats were designated as destination points.

For this study, dry bulk fertilizers were combined into two separate categories: dry bulk nitrogen fertilizers and dry bulk phosphate fertilizers. Liquid fertilizers were also combined. Anhydrous ammonia estimates were treated separately. Projected 1980 demands for these product groupings were previously determined in a research report compiled for the Army Corps of Engineers. The network model and transportation linear

programming model were combined to analyze the data assuming varying cost and supply conditions.

Fertilizer shipment costs were developed for four modes of transport: railroad, truck, pipeline and barge. Pipeline and barge costs were treated as a transhipment cost and added to rail and truck shipments at specified origin points.

From the analyses portion of this study, it was determined that intermodal combinations of rail and truck services provide the most economical means of fertilizer distributions to the study area. It was also determined that the railroad and trucking industries are in close competition as indicated by the shift to rail service as rail costs were reduced.

In the anhydrous ammonia analyses, due to the proximity of origins to destinations, truck service is the most utilized mode of transport assuming railroads operate at fully-distributed cost levels. When rail costs are reduced 20 percent, to reflect approximately one-half of allocated fixed costs being recovered, rail service increased from 7 percent to 12 percent. A 40 percent reduction in rail costs increased rail service to 39 percent.

In the liquid fertilizer analyses, rail service also increased as rail costs were lowered. A 20 percent reduction in rail costs increased rail service 41 percent. A 40 percent reduction only increased rail service by 1 percent over the 20 percent reduction analysis.

Rail service also increased in the dry bulk fertilizer analyses as rail costs were reduced. A 20 percent reduction increased rail service from 42 percent to 85 percent. A 40 percent rail cost reduction caused a complete shift to rail service.

In the dry bulk phosphate analyses, it was determined that rail service from Greenbay, Florida provides the most economical direct rail transportation to the study area. It was also determined that a barge-rail combination from Tampa, Florida via Kansas City, Kansas results in the most economical way to move dry bulk phosphate to the study area from the origins selected for the purpose of this study.